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Office of Radiation Programs

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr'a
10^{9}	giga	G	jĭ'ga
10^{6}	mega	M	mĕg'a
10^{3}	kilo	k	kĭ'lo
10^{2}	hecto	h	hĕk'to
10	deka	da	dĕk'a
10^{-1}	deci	d	dĕs'i
10^{-2}	centi	c	sĕn'ti
10^{-3}	milli	m	mĭl'i
10^{-6}	micro	μ	mī'kro
10^{-9}	nano	n	năn'o
10^{-12}	pico	p	pē'ko
10^{-15}	femto	f	fĕm'to
10^{-18}	atto	a	ăt'to

SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
Å	angstrom	10^{-10} meter
a	annum, year	
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb.
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi/m^2 (mCi/km^2)
MeV	million (mega) electron volts	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m^2	nanocuries per square meter	2.59 mCi/mi^2
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose	100 ergs/g

RADIATION DATA AND REPORTS

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Radiation Data and Reports, a monthly publication of the Environmental Protection Agency, presents data and reports provided by Federal, State, and foreign governmental agencies, and other cooperating organizations. Pertinent original data and interpretive manuscripts are invited from investigators.

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels. This responsibility was delegated to the Bureau of Radiological Health, Public Health Service. Pursuant to the Reorganization Plan No. 3 of 1970, effective December 2, 1970, this responsibility was transferred to the Radiation Office of the Environmental Protection Agency which was established by this reorganization.

The Federal agencies listed below appoint their representatives to a Board of Editorial Advisors. Members of the Board advise on general publications policy; secure appropriate data and manuscripts from their agencies; and review those contents which relate to the special functions of their agencies.

Department of Defense
Department of Agriculture
Department of Commerce
Department of Health, Education, and Welfare
Environmental Protection Agency
Atomic Energy Commission

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U.S. ENVIRONMENTAL PROTECTION AGENCY

William D. Ruckelshaus, Administrator

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference card format for the convenience of readers who may wish to clip them for their files.

ENVIRONMENTAL RADIOACTIVITY IN MICHIGAN, 1970. *Samuel Wieder, Joe E. Logsdon, and Charles P. Froom. Radiation Data and Reports, Vol. 13, January 1972,* pp. 3–18.

This report summarizes the radioactivity from all major sources measured in the Michigan environment during 1970. It also describes the State's environmental surveillance programs and the data resulting from these programs. Surveillance data provided by Federal, State, operator, and contractor sources are summarized. On the basis of this information, an estimate is presented of annual radiation doses to the population of Michigan. A summary of some operating characteristics of Big Rock Point, Enrico Fermi-1 and Palisades plants is presented.

KEYWORDS: Michigan, environmental, nuclear power, radioactivity, reactors, surveillance.

A SUMMARY OF ENVIRONMENTAL RADIATION SURVEILLANCE ACTIVITIES IN ARKANSAS. *Burvie H. Sheets, William H. Oates, Jr., David D. Snellings, Jr. and E. Frank Wilson. Radiation Data and Reports, Vol. 13, January 1972,* pp. 19–26.

This report describes the environmental radiation surveillance program of the Division of Radiological Health, Arkansas State Department of Health. The program has been broken down into two general categories: (1) statewide system and (2) source oriented surveillance activities. There are two nuclear facility sites in Arkansas and extensive surveillance activities are presently being conducted near each site. Some of the data that was collected during the time period 1966 through 1970 has been presented.

KEYWORDS: Arkansas, air, grass, milk, offsite surveillance, nuclear power reactor, radioactivity, silt, soil, water.

Radioactive Discharges and Environmental Surveillance Associated with Nuclear Power Plants

Radioactivity in the environment has many sources, and these result in population exposure through several pathways. In order to estimate population dose from environmental radiation it is necessary to know the concentrations or levels in each exposure pathway. The reduction or control of population exposure requires a knowledge of the sources of environmental radiation and of the pathways from these sources to man.

The sources of greatest environmental radiation exposure to the population are natural background radioactivity and fallout from past nuclear weapons tests conducted in the atmosphere. These sources generally do not lend themselves to control, but because of their variability with time and location, it is important to measure them on a continuing basis in order to ascertain and to evaluate any contributions that may arise from controllable sources of environmental radiation. Cognizance is taken of the impact of medical x-ray exposure on the population through the genetically significant dose concept.

Nuclear facilities which release radioactive wastes to the environment represent a controllable source of environmental radiation; hence it is appropriate to assess the contribution of these sources to population dose. Releases from nuclear power operations contribute a very small part of the total population exposure to ionizing radiation. Such releases, however, increasingly engage the concerns of environmental and public health authorities and the public, because the number and output of nuclear power and supporting facilities are increasing.

A measure of the projected increase in nuclear power plants in the United States may be obtained from the following tabulation:[1]

	Number	Capacity (kWe)
Plants operable	22	9,131,800
Plants being built	55	46,605,000
Planned (reactors ordered)	49	48,524,000
Totals	126	104,260,800

For purposes of gaining perspective with respect to population exposure in the light of the anticipated growth of the industry, it is important to document such factors as: releases to the environment, population distributions around reactor sites, and all sources and vectors that bear upon radiation exposure to people in the region that may be materially affected by releases of radiation from nuclear power operations.

Data on radiological surveillance of areas in which nuclear power reactors are situated will be reported as they become available, on a regional or State-by-State basis, as appropriate. As this program proceeds it is anticipated that a perspective of the national picture will develop. *Radiation Data and Reports* will present data for various regions or States on a rotating basis, so that as many regions as can feasibly be covered may be represented during each year.

[1] As of September 30, 1971; source, AEC news release.

Data sources will include reactor licensees, the Environmental Protection Agency, the Atomic Energy Commission and its contractor facilities, States, and special contractors such as universities and others. As a basis for the presentation of these surveillance reports, it will naturally be necessary for the State or region to have one or more nuclear facilities with associated surveillance programs, including data on discharges of radioactivity.

With the development of guides to the preparation of environmental reports for nuclear power plants, it is anticipated that regional reports will become more complete and increasingly amenable to intercomparison.

In this issue of *Radiation Data and Reports,* data are presented which relate to environmental radioactivity in Michigan for 1970.

Reports

Environmental Radioactivity in Michigan, 1970

Samuel Wieder, Joe E. Logsdon, and Charles P. Froom[1]

This report summarizes the radioactivity from all major sources measured in the Michigan environment during 1970. It also describes the State's environmental surveillance programs and the data resulting from these programs. Surveillance data provided by Federal, State, operator, and contractor sources are summarized. On the basis of this information, an estimate is presented of annual radiation doses to the population of Michigan. A summary of some operating characteristics of Big Rock Point, Enrico Fermi-1 and Palisades plants is presented.

The State of Michigan had two nuclear power plants functioning during 1970—Big Rock Point and Enrico Fermi–1. The Big Rock Point facility has been in operation since 1962. The Enrico Fermi–1 plant, a fast breeder reactor which began operations in 1963, was shutdown in October 1966 as a result of fuel element damage. It resumed full power tests late in 1970. Although the Palisades plant was originally scheduled to start up in 1970, test operation at low power (not to exceed 1 megawatt thermal) did not begin until the spring of 1971. A summary of some characteristics of operating and planned nuclear power plants in Michigan appears in table 1; their locations are shown in figure 1.

Data on the environmental impact of the Big Rock Point plant—the only nuclear power reactor operational during the entire year—are too limited for 1970 to permit accurate estimates of dose to the local population, and some types of sampling showed radioactivity levels no higher than are normally found in Michigan. However, an estimate of the maximum hypothethical dose to an individual, based on conservative assumptions is attempted. With expanded and coordinated data collection in the future, more accurate assessments of population exposures should be possible.

A variety of radioactivity surveillance studies have been made in the State. Routine surveillance activities are conducted by the Michigan Department of Public Health, Michigan Water Resources Commission (Department of Natural Resources), the Environmental Protection Agency (EPA), and the nuclear power plant operators. A summary of these programs is provided in table 2. In addition, special surveys of Lake Michigan were performed by the University of Michigan for 1969–1970. Argonne National Laboratory also determined environmental radionuclide concentrations near the Big Rock Point reactor.

Environmental surveillance around nuclear power reactors

Big Rock Point

Big Rock Point Nuclear Power Station uses a boiling water reactor. Among other specifications, its design characteristics provide for high-efficiency particulate filters and piping to permit 30-minute delay prior to discharge of gases through a 240-foot stack. Initial dilution of radioactive gases is provided by a flow of 30,000 cubic feet per minute of ventilation air. Gaseous waste discharges are limited by technical specifications to 1 curie per second for fission and activation gases.

[1] Messrs. Wieder and Logsdon are with the Surveillance and Inspection Division, Office of Radiation Programs, Environmental Protection Agency, Washington, D.C. 20460. Mr. Froom is with the Bureau of Radiological Health, FDA.

Table 1. Nuclear power facilities in Michigan

Name of facility	Operator	Reactor type[a]	Power level (MWe)	Year of startup	Location	Population within 10 miles[b]
Big Rock Point	Consumers Power Company of Michigan	BWR	70.3	1962	Big Rock Point	11,000
Enrico Fermi-1	Power Reactor Development Company	FBR	60.9	1963	Lagoona Beach	61,000
Palisades	Consumers Power Company of Michigan	PWR	700	1971	South Haven	28,000
Donald C. Cook-1	Indiana and Michigan Electric Company	PWR	1,054	1972	Bridgman	
Donald C. Cook-2	Indiana and Michigan Electric Company	PWR	1,060	1973	Bridgman	
Midland-1	Consumers Power Company of Michigan	PWR	492	1974	Midland	
Enrico Fermi-2	Detroit Edison Company	BWR	1,123	1973	Lagoona Beach	
Midland-2	Consumers Power Company of Michigan	PWR	818	1975	Midland	

[a] BWR-boiling water reactor; FBR-fast breeder reactor; PWR-pressurized water reactor.
[b] Operating facilities only.

Liquid radioactive waste discharges average about 780 gallons per day from various plant drains, demineralizer regeneration liquids, laundry, and miscellaneous low-level wastes. The system is designed to handle about 70,000 gallons per day.[2] Releases are on a batch basis under controlled flow. These wastes go into a discharge canal and thence into Lake Michigan.

The Big Rock Point reactor has been part of an extensive research and development program testing fuels and fuel claddings. Consequently, it has experienced more fuel failures —and thus has had more fission products in its waste effluents—than might be expected if operations were of more routine nature.

The operating history of the Big Rock Point reactor was summarized in a report by Logsdon and Chissler (*1*). In general, gaseous waste discharges tended to increase during the first few years of operation. Then beginning in 1967, with continued operation, they declined, although there was no reduction in power generation. No similar trend was ascertainable in liquid waste discharges. During 1970, total curies of gross beta activity, less tritium, in liquid-waste discharges were 61 percent less than during the previous year. Total curies of gaseous waste discharges were down 15 percent in 1969 and up 38 percent in 1970.

Table 3 lists, for 1970, gross beta analyses of environmental samples for various locations around the Big Rock Point plant. Comparison of these data with similar data collected around Palisades—which was not yet in operation—(table 3 and 10) indicates some radioactivity increase in air or precipitation around Big Rock Point. However, comparison of data on radioactivity in shore minnows collected near the Big Rock Point reactor indicated an increase of from 10 to 30 times the radioactivity in minnows collected in the vicinity of the Pali-

[2] The primary source of liquid waste radioactivity resulted from regeneration of condensate demineralizer resins. Early in 1971, an administrative procedure was enacted to discontinue regeneration and discard the resins for offsite burial when spent. This has substantially reduced the amount of radioactive liquid waste discharged to the lake (personal communication, R. W. Linderman, Consumers Power Company).

Figure 1. Nuclear power plants in Michigan

sades plant. The data from samples of filamentous algae collected near Big Rock show concentrations of radioactivity approximately three times greater than in similar samples collected near Palisades.

During June, July, and October 1970, Argonne personnel collected water, sediment, and biological samples near Charlevoix, and analyzed these for gamma-ray emitting nuclides (*2*). A summary of the findings follows.

Water The radioactive effluent from the Big Rock Point reactor (which is mixed with the cooling water and discharged through a shoreline channel) consists of periodic releases of liquid waste. This variability of source activity —in addition to the variable nature of lake currents—decreases the usefulness of data derived from short-term samples taken at some distance from the source, e.g., from Lake Michigan waters. Table 4 shows concentrations of five gamma-emitting radionuclides in samples of water collected with a Battelle large volume ocean sampler, which forces water through a filter and ion-exchange-resin-bed combination. These data show easily measured concentrations in the discharge channel and detectable levels as far as ¼ mile beyond the channel.

Near-shore organisms For purposes of defining the area of influence of the radiation from waste discharges at Big Rock Point, measurements of radionuclide concentrations were made in organisms at various distances from the point of discharge. The organisms investigated were either attached to the bottom or had a limited range, and were both abundant and easy to gather. These were counted wet and then oven-dried at 100° C. to obtain dry

Table 2. Summary of surveillance programs in Michigan, 1970

Sample type	EPA Network			State Program			Enrico Fermi Program			Palisades Program			Big Rock Point Program		
	Number of sample locations	Frequency of collection	Type of analysis	Number of sample locations	Frequency of collection	Type of analysis	Number of sample locations	Frequency of collection	Type of analysis	Number of sample locations	Frequency of collection	Type of analysis	Number of sample locations	Frequency of collection	Type of analysis
Air particulate	1	Daily	Gross β	14	Weekly	Gross β	10	Weekly	Gross β	12	Weekly	[a]	7	Weekly	Gross β, ^{131}I
Surface water	4	Quarterly	^{3}H	51	Annually	Gross β	8	Weekly	Gross β	1	Monthly composited quarterly	Gross β, Gross γ, ^{3}H, ^{137}Cs, ^{90}Sr, ^{131}I	[b]2	Monthly composite	Gross β, Gross γ, ^{59}Fe, ^{60}Co, ^{65}Zn, ^{90}Sr, ^{137}Cs
Precipitation	1	Daily	Gross β	14	Weekly	Gross β	5 offsite 5 onsite	Monthly Monthly	Gross β Gross β ^{141}Ce, ^{144}Pr, ^{95}Zr-Nb, ^{103}Ru, ^{106}Ru-Rh, ^{54}Mn, ^{137}Cs						
Well water										3	Monthly	Gross β, ^{131}I, ^{137}Cs, ^{90}Sr, ^{59}Fe, ^{60}Co, ^{65}Zn			
Drinking water	1	Quarterly	^{3}H	48	Quarterly	Gross β Gross α									
Sediment							2	Quarterly	^{137}Cs, ^{226}Ra, ^{40}K						
Human bone	Varies 21 in 1970	Varies	^{90}Sr/Ca ratio												
TLD and film				14	Monthly	Gamma dose	10	Monthly	Gamma dose	[c]21	Monthly and quarterly	Gamma dose	[d]21	Monthly	Gamma dose
Vegetation										5	Monthly in season	Gross β, Gross γ			
Milk	2	Weekly Jan–June monthly July–Dec	$^{89,90}Sr$, ^{137}Cs, ^{131}I, ^{140}Ba	8	Weekly an monthly	^{90}Sr, ^{137}Cs, ^{131}I, ^{140}Ba-La	4	Monthly	Gross β, ^{137}Cs, ^{40}K	3	Monthly	^{131}I, ^{90}Sr, ^{137}Cs, ^{140}Ba-La			
Fish				6	2/a	Gross β	4	Quarterly	Gross β, ^{141}Ce, ^{144}Pr, ^{95}Zr-Nb, ^{103}Ru, ^{106}Ru-Rh, ^{54}Mn, ^{137}Cs						
Other aquatic biota				6	2/a	Gross β				1	Varies	Gross β, Gross γ, Gamma scan	5	Annually	Gross β, Gross γ, Gamma scan

[a] Gross β and ^{131}I analysis at all sites; ^{90}Sr, ^{137}Cs, and ^{140}Ba-La at only one site.
[b] Condenser cooling water inlet and outlet; radionuclide analysis only on outlet sample.
[c] Includes 9 on the site boundary.
[d] Includes 14 on the site boundary and control dosimeters.

Table 3. Gross beta radioactivity in environmental samples, Big Rock Point Reactor, 1970

Sample type	Location	Distance from Big Rock Point plant	Frequency of collection	Radioactivity		Number of samples
				Range	Mean	
Air particulate[a] (pCi/m³)	Charlevoix	4 miles-SW	Weekly	0.059– 0.80	0.259	51
	Reactor site			.063– .70	.256	49
	Burgess	2 miles-ESE		.073– .88	.268	51
	Nine Mile Point	3 1/2 miles-ENE		.069– .71	.224	47
	Oyster Bay	2 1/2 miles-S		.067– .94	.260	52
					0.252	250
Air particulate[b] (pCi/m³)	Big Rock Point Plant		Weekly	.010– .40	.11	52
	Nine Mile Point	3 1/2 miles-ENE		.010– .41	.19	53
	Charlevoix	4 miles-SW		.014– .53	.12	53
	South of Susan Lake			.014– .44	.15	23
	Petoskey			.010– .40	.13	49
	Boyne City			.010– .52	.15	37
	Traverse City			.020– .57	.12	42
					0.14	309
Precipitation[a] (pCi/liter)	Charlevoix		Weekly	.17 – 49	16.5	19
	Reactor site			.37 – 91	30.0	19
	Burgess			1.3 – 120	33.2	19
	Nine Mile Point			.69 – 130	48.1	20
	Oyster Bay			1.8 – 120	36.2	18
					32.8	95
Deposition from precipitation[a] (pCi/m²-day)	Charlevoix		Weekly	1.5 – 130	39.8	19
	Reactor site			3.6 – 230	88.9	19
	Burgess			5.7 – 230	98.6	19
	Nine Mile Point			5.0 – 280	116.2	20
	Oyster Bay			7.1 – 230	88.8	18
					86.5	95
Drinking water[a] (pCi/liter)	Samples from 48 sites	Throughout State	Quarterly to semiannually	< .94 – 8.4	3.1	107
	Charlevoix			2.0 – 3.4	2.7	
	Petoskey			2.0 – 3.6	2.8	
	Traverse City			3.2 – 4.2	3.7	
	Elk Rapids			<.94 – 2.4	1.7	
Surface water[a] (pCi/liter)	Lake Michigan-Charlevoix			ND–10	9	
	Susan Creek at U.S. 31			ND	ND	
	Little Traverse Bay, 2 miles west of Petoskey			ND	ND	
	Lake Michigan-Petoskey			ND	ND	
	Bear River-Petoskey			ND–16	11	
Filamentous algae[c] (pCi/g)	Big Rock Point Plant		2/annum	340 – 340	340	2
	Nine Mile Point	3 1/2 miles-ENE	2/annum	112 – 120	116	2
	Mt. McSauba Point	2 1/2 miles-SW	2/annum	56 – 130	93	2
					183	6
Periphyton[c] (pCi/g)	Big Rock Point Plant		2/annum	71 – 210	140	2
	Nine Mile Point		2/annum	21 – 80	50	2
	Mt. McSauba Point		2/annum	34 – 37	35	2
					75	6
Shore minnows[c] (pCi/g)	Big Rock Point Plant		2/annum	250 – 580	415	2
	Nine Mile Point		2/annum	15 – 19	17	2
	Mt. McSauba Point		2/annum	6.3 – 15	11	2
					148	6
Crayfish[c] (pCi/g)	Big Rock Point Plant		2/annum	400 –1,050	725	2
	Nine Mile Point		2/annum	14 – 22	18	2
	Mt. McSauba Point		2/annum	18.5 – 25	22	2
					255	6

[a] Data from Michigan Department of Public Health.
[b] Data from Consumers Power Company surveillance program.
[c] Data from Michigan Water Resources Commission.
ND, nondetectable.

Table 4. Radionuclide concentrations in water, Big Rock[a]

Sample	Radioactivity (pCi/liter)				
	^{134}Cs	^{137}Cs	^{95}Zr	^{65}Zn	^{60}Co
In channel before release:[b]					
Filter	0.01	<0.01	<0.005	0.14	<0.005
Cation resin	.032	.048	.005	< .05	< .05
In channel during release:[c]					
Filter	5.0	17.0	.24	33.0	1.1
Cation resin No. 1	16.0	53.0	.1	.43	.04
Cation resin No. 2	26.0	82.0	<.1	<.05	<.05
1/4 mile off channel during release:[d]					
Filter	.30	.87	.01	1.3	.05
Cation resin	.55	1.8	.01	.09	<.005

[a] Data from Argonne National Laboratory study.
[b] Sample taken October 18, 1970, the day before a scheduled release.
[c] Sample taken next day, about halfway through an 8-hour release.
[d] Collected about 1 hour later, 1/4 mile directly offshore (discharge still in progress).

weights. Data are reported on a dry weight basis (table 5).

Concentration values for the five radionuclides reported in water, plus potassium, were determined in crayfish, water snails, the aquatic macrophytes *Potamogeton* sp. (pondweed) and *Ranunculus* sp. (a herbaceous plant), the green algae *Chara* sp., *Cladophora* sp., and *Periphyton*.

As expected, all species showed marked decreases in concentration with increasing distance from the discharge point. The rate of decline in concentration was more rapid westward of the outfall than to the east of the outfall. The approximately constant cesium-137/cesium-134 ratio indicates an approximately equal cesium input from the plant and from fallout, at least within a few miles.

Sediments The difficulty of finding sandy patches on the generally rocky bottom made the 1970 lake bottom sampling program spotty. A number of samples were taken at various distances directly offshore from the discharge channel, as well as along the beach in both directions from the plant. In general, the samples consisted of sand and gravel mixtures. After air drying, the samples were sifted and the fraction passing through a No. 30 U.S. Standard sieve (0.595-mm opening) was gamma counted. As can be seen from the data in table 6, the wide variations among samples

Table 5. Radioactivity concentrations in near-shore organisms, Big Rock[a]

Sample	Feet from outfall	^{134}Cs (pCi/g)	^{137}Cs (pCi/g)	^{95}Zr (pCi/g)	^{65}Zn (pCi/g)	^{60}Co (pCi/g)	K (g/kg)	$\frac{^{137}Cs}{^{134}Cs}$
Crayfish	14,000 west	0.25	1.4	<0.4	3.8	<0.2	12	5.6
	4,000 "	.57	1.9	< .4	12.4	.6	15	3.3
	2,500 "	.73	2.2	.2	15.1	.73	11	3.0
	<500	4.5	15	1.7	118	2.32		3.3
	Outfall	10.1	54	3.8	620	17.4		5.3
	Outfall	7.4	35	1.6	365	6.95		4.7
	3,000 east	.73	3.8	.14	51	.23	11	5.2
	5,000 "	.58	3.4	< .4	61	.5	16	5.9
	14,000 "	.35	1.9	.52	15.6	.14	9	5.4
Snails	Outfall	6.37	25.8	2.3	184	13.8		4.0
	1,500 east	.80	4.92	.5	47	6.28	13	6.1
Potamogeton sp	3,000 west	< .1	.18	3.8	6.6	.59	14	>2
	2,500 "	.32	.43	3.4	16.3	.40	13	1.3
	1,500 "	.45	.50	3.4	23.1	.29	<10	1.1
	500 "	< .2	.63	2.6	20.2	.20	14	>3
	500 east	3.1	6.3	4.2	285	15.6	18	2.0
	1,500 "	< .5	1.8	3.2	152	2.95	19	>3
	3,000 "	.47	1.0	3.2	66	2.08	16	2.1
	4,000 "	.49	.77	2.4	46	1.94	11	1.6
Ranunculus sp	3,000 east	1.6	4.6	.6	266	2.14	30	2.9
	4,000 "	.6	2.6	< .4	177	3.70	30	4.3
Chara sp	1,500 east	1.8	2.9	<2	178	13.7	<30	1.6
Cladophora sp	4,000 west	.4	1.6	30.8	4.4	.22	86	4.0
	3,000 "	< .15	1.7	19.2	2.9	.16	50	>11
	2,000 "	2.1	7.1	20	100	3.9	59	3.4
	<500 east	15.2	39.4	35.2	344	23.0	38	2.6
	500 "	4.3	16.8	15.8	179	6.9	43	3.9
	1,000 "	1.7	6.3	10.2	58	1.7	49	3.7
	1,500 "	1.0	4.1	14.8	47	1.2	57	4.1
	8,000 "	1.3	3.5	27.2	11.0	.64	58	2.7
Periphyton	14,000 west	0.43	1.79	1.4	1.9	.05	3	4.2
	<500	38.4	86.5	17.9	1,980	124		2.3
	14,000 east	1.6	3.4	8.1	22.1	.77	5	2.1

[a] Data from Argonne National Laboratory Study. All weights are dry weights.

Table 6. Radioactivity in bottom sands, Big Rock[a]

Distance from outfall (feet)	Distance offshore (feet)	^{134}Cs (pCi/g)	^{137}Cs (pCi/g)	^{95}Zr (pCi/g)	^{65}Zn (pCi/g)	^{60}Co (pCi/g)	^{40}K (pCi/g)	$\frac{^{137}Cs}{^{134}Cs}$
20,000 west	2,000	0.014	0.20	0.006	0.01	0.014	11	14
4,000 west	<200	.065	.57	.03	.20	.026	7	9
3,000 west	<100	.033	.39	.008	.05	.010	7	12
At outfall	100	2.15	6.34	< .2	20.1	2.60	7	2.9
At outfall	100	1.58	5.60	.1	15.3	3.22	11	3.3
At outfall	100	.57	1.97	.03	2.8	.36	9	3.5
At outfall	200	3.32	10.3	.3	61.4	6.75	8	3.1
At outfall	500	.63	2.79	< .1	4.8	.86	7	4.4
At outfall	500	.68	2.66	< .1	3.1	.51	5	3.9
At outfall	2,000	.40	1.57	.2	11.2	2.46	13	3.9
1,500 east	<100	.35	2.31	.12	9.3	.97	7	6.6
3,000 east	<100	.66	2.68	.09	3.9	.45	10	4.1
4,000 east	<100	.10	.77	< .02	.63	.09	7	7.7
5,000 east	<100	.08	.68	.06	.15	.07	8	8.5
10,000 east	<200	.11	.56	< .05	.46	.11	9	5.1

[a] Data from Argonne National Laboratory study. All weights are dry weights.

from the discharge channel points up the difficulty of obtaining representative grab bottom samples at this site.

Fish Since fish are potentially a human food source, they must be considered when studying the radiological health aspects of releases from nuclear facilities. It is desirable to take large numbers of samples for study, in view of the mobility of the organisms and the variability of the sources of radioactivity. The 1970 samples taken by Argonne (table 7) are composites of several whole fish, mostly below edible size, taken from the discharge channel. From these samples it would appear that the fish studied have lower radionuclide concentrations than do other biota in the vicinity. In addition, analyses indicated that the zinc-65 concentration in the edible portions is about one-fourth that of the whole fish.[3]

Discharges Operator reports on liquid and gaseous discharges during 1970 are summarized in table 8. A total of 4.68 curies, excluding tritium, of liquid wastes and 277,500 curies of gaseous wastes were discharged. All batches of liquid discharges were identified by isotopic composition; approximately 45 percent of the activity was due to zinc-65. The remainder was composed mainly of cesium-134, cesium-137 and iodine-131.

[3] D. M. Nelson, personal communication.

Table 7. Radioactivity in fish, Big Rock[a]

Sample	Location	^{134}Cs (pCi/g)	^{137}Cs (pCi/g)	^{95}Zr (pCi/g)	^{65}Zn (pCi/g)	^{60}Co (pCi/g)	^{40}K (g/kg)	$\frac{^{137}Cs}{^{134}Cs}$
Bluegill: No. 1	Outfall	1.05	3.95	0.3	34.5	1.21	10	3.8
No. 2	Outfall	1.03	5.44	< .05	15.4	.65	12	5.3
No. 3	Outfall	2.23	8.19	.1	86	.89	10	3.7
No. 4	Outfall	1.59	6.27	.2	51	.05	13	3.9
Alewife: No. 1	Outfall	.92	5.71	< .15	138	1.1	13	6.2
No. 2	Outfall	.19	.91	< .05	4.43	.10	11	4.8
No. 3	Outfall	< .1	.67	< .05	.86	.16	11	>7
Bass: No. 1	Outfall	.22	2.06	< .06	6.7	.07	14	9.4
No. 2	Outfall	.30	3.19	.1	6.0	.6	14	10.6
No. 3	Outfall	.27	1.77	< .1	1.3	< .06	10	6.6
Sunfish	Outfall	.33	1.06	< .06	4.2	.2	10	3.2
Sucker	Outfall	< .1	1.03	< .05	< .3	< .03	16	>10
Average		0.70	3.4	0.11	29	0.43	12	

[a] Data from the Argonne National Laboratory study. Weights expressed are dry weight, which is 20 to 25 percent of wet weight values.

Table 8. Gross discharge of radioactivity from Big Rock Point nuclear plant, 1970[a]

Month (1970)	Gaseous discharges (Ci)	Liquid discharges		
		Batches	Gallons	Activity (mCi)[b]
January	40,900	3	14,885	92.9
February	19,500	5	24,035	56.9
March	79	11	54,795	785.0
April	3,490	3	13,660	98.6
May	4,060	4	18,850	199.2
June	3,870	5	25,580	296.2
July	5,320	4	19,750	330.0
August	7,850	6	28,005	1,222.4
September	22,200	4	19,750	207.2
October	41,900	7	31,800	379.4
November	48,200	3	15,685	786.0
December	80,200	4	18,175	228.1
Total	277,569	59	284,970	4,681.9

[a] Data from Consumers Power Company operating reports.
[b] Excluding tritium.

Enrico Fermi-1

This facility is a liquid sodium-cooled fast breeder reactor. Its design characteristics include a stack of 200 feet high and a stack exhaust rate of 1,390,000 cubic-feet-per-minute. It has absolute filters for particulates, no installation for iodine treatment, and a holdup capacity for gaseous radioactive wastes of up to 4 months. Liquid wastes are released into Lake Erie on a controlled basis.

During operations from August 1963 until shutdown in 1966, radioactive gaseous waste discharges ranged from 7×10^{-4} to 1.4×10^{-2} curies per year. The latter represents 2×10^{-3} percent of the concentration limit of 2×10^{-6} $\mu Ci/cm^3$ in the discharge stack.

During shutdown, gaseous radioactive waste discharges were not measurably different from normal background. Radioactivity in liquid waste discharges, on the other hand, could be detected throughout the shutdown period. This is to be expected in consequence of continuing decontamination operations. For 1969—the most recent full year of shutdown—a total of 63,700 gallons, containing 0.053 curies, was discharged. This represented 0.22 percent of the discharge limit. No tritium discharge values were reported. Activity during the first month of 1970 showed a decline to a rate of about one-third of the 1969 values. Full power tests began late in 1970.

Data on discharges for 1970, supplied by the facility operators, indicate that discharges were low. Gaseous waste discharges from the stack were below detectable levels. Liquid discharges amounted to a total of 40.4 millicuries. A sample of Lake Erie water taken north of the plant on October 22, 1969, had a tritium concentration of 1 ± 0.7 nanocurie per liter (*3*). Two additional samples collected on that date had concentrations below the detectable level of 0.7 nCi/liter. A surface water sample from Lake Erie in the vicinity of Lagoona Beach was taken on September 12, 1970, for tritium analysis. Tritium activity was found to be below the detectable limit of 0.6 nanocurie per liter.

Surveillance around the Fermi reactor is conducted by the State of Michigan and the Detroit Edison Company. Analytical data for gross beta radioactivity in environmental samples for 1970 are given in table 9. The table includes corresponding data for Lansing, which serves as a control station.

Palisades Nuclear Power Station

The construction permit for this plant was issued in March 1967. Although commercial operation was planned for 1970, authorization for fuel loading and low power (not to exceed 1 megawatt thermal) testing was not granted by the Atomic Energy Commission until March 1971. The Palisades plant design provides for holdup of radioactive gaseous waste for at least 30 days, allowing the decay of short-lived radionuclides. The plant lies within the drainage basin of Brandywine Creek, which flows into Lake Michigan.

Environmental surveillance activities in the vicinity of this plant for 1970 serve as part of the preoperational surveillance program. Environmental surveillance data for the area are shown in tables 10 and 11. Since the Palisades plant was not operational during 1970, these data may be considered background levels.

Lake Michigan survey

Lake Michigan surveillance for environmental radioactivity was performed for the period July 1969–June 1970 by the University of

Table 9. Gross beta radioactivity in environmental samples, Enrico Fermi–1 reactor, 1970

Sample type	Location	Distance from Enrico Fermi Plant	Frequency of collection	Radioactivity		Number of samples
				Range	Mean	
Air particulate:[a] (pCi/m³)	Carleton	7 miles-NW	Weekly	0.053– 0.54	0.225	52
	Monroe	6 miles-WSW		.069– .56	.216	43
	Rockwood	7 miles-NNE		.054– .75	.259	33
	Reactor site			.061– .70	.235	47
	Lansing[b]	85 miles-NW		.035– .66	.206	51
					0.234	177
Precipitation:[a] (pCi/liter)	Carleton		Weekly	9 – 330	80	27
	Monroe			12 – 190	58	27
	Rockwood			12 – 605	85	29
	Reactor site			17 – 470	75	26
	Lansing[b]			16 – 920	130	29
					86	109
Deposition from precipitation:[a] (pCi/m²-day)	Carleton		Weekly	25 – 580	290	27
	Monroe			17 – 480	138	27
	Rockwood			15 – 400	133	29
	Reactor site			40 – 310	139	26
	Lansing[b]			22 – 1,300	291	29
					175	109
Air particulate:[c] (pCi/m³)	5 locations on site		Weekly	.076– .914	.275	260
	Monroe	8 miles-WSW	Weekly	.062– .913	.27	52
	Carleton	10 miles-NW		.037– .715	.25	52
	Flat Rock	9 miles-N		.056– .827	.27	52
	Trenton	14 miles-NNE		.069– .786	.26	52
	Ann Arbor	85 miles-NW		.055– .914	.27	52
						260
Surface water:[c] (pCi/liter)	Reactor channel		Weekly grab	3.1 – 29	8.0	52
	Swan Creek			3.3 – 33	10	52
	Lake Erie			2.6 – 49	7.2	52
	Monroe-Lake Erie		Weekly daily composite	3.8 – 8.3	5.1	52
	Flat Rock-Huron River			3.6 – 18.9	7.1	52
	Huron River:					
	Ypsilanti				12	
	Flat Rock			[d]ND–12	10	
	Rockwood				ND	
	Estral Branch			ND–10	9	
	Lake Erie-Monroe			ND–12	10	
	Raisin River: Monroe			ND–18	12	
	Dundee			ND	ND	
	Swan Creek-Estral Branch			ND	ND	
	Dundee-Raisin River			4.7 – 27.7	8.0	52
	Toledo-Lake Erie			3.2 – 18.7	5.5	52
	Detroit-Lake St. Clair			2.7 – 12.1	4.3	52
	Allen Park-Detroit River			2.6 – 7.9	4.3	52
	Ann Arbor-Huron			1.7 – 16.6	5.8	52
	Colchester-Lake Erie			2.7 – 26.2	6.4	52
					5.8	312
Drinking water (pCi/liter)	Flat Rock			3.4 – 6.4	5.0	
Deposition:[c] (pCi/m²-day)	5 locations on site		4 weeks	32 – 585	242	65
	Monroe	8 miles-WSW	4 weeks	47 – 655	239	13
	Carleton	10 miles-NW		37 – 816	265	13
	Flat Rock	9 miles-N		47 – 571	228	13
	Trenton	14 miles-NNE		31 – 806	289	13
	Harrow			44 – 672	228	13
					249	65
Milk:[c] (reactor group-pCi/liter)	Monroe		4 weeks	603 – 1,640	1,080	13
	Newport			796 – 1,520	1,070	13
					1,075	26
Milk:[c] (background group-pCi/liter)	McCalla, Ypsilanti		4 weeks	645 – 1,570	1,060	13
	Bolgos, Ann Arbor			541 – 1,450	1,060	13
					1,060	26

See footnotes at end of table.

Table 9. Gross beta radioactivity in environmental samples, Enrico Fermi–1 reactor, 1970—continued

Sample type	Location	Distance from Enrico Fermi Plant	Frequency of collection	Radioactivity		Number of samples
				Range	Mean	
Fish:[c] (pCi/g-wet)						
Perch	Reactor area		Quarterly	0.96 – 5.01	2.42	9
	Buffalo area			1.28 – 3.06	2.13	12
					2.28	21
Bass	Reactor area		Varies	1.24 – 2.37	1.69	9
	Buffalo area			2.16 – 2.83	2.42	3
					2.06	12
Smelt	Buffalo area		Varies	1.35 – 1.81	1.59	6
Shad	Reactor area		Varies	1.69 – 2.10	1.88	3
Whitefish	Buffalo area		Varies	2.69 – 2.97	2.81	3

[a] Data from Michigan Department of Public Health.
[b] Lansing, a control surveillance station, is not included in calculation of mean activity or sample count for surveillance stations around Enrico Fermi.
[c] Data from Detroit Edison Company. The data covers the period December 24, 1969 to November 25, 1970.
[d] ND, nondetectable for gross beta = <9 pCi/liter.

Table 10. Gross beta radioactivity in environmental samples, Palisades reactor, 1970[a]

Sample type	Location	Distance from Palisades Plant	Frequency of collection	Radioactivity		Number of samples
				Range	Mean	
Air particulate: (pCi/m³)	South Haven	4 1/2 miles NNE	Weekly	0.059– 0.92	0.264	41
	Rendall service station	4 miles SSW		.08 – .74	.311	34
	Covert	4 miles SE		.065– .64	.248	41
	Reactor site			.071– .63	.244	42
					0.267	158
Precipitation: (pCi/liter)	South Haven		Weekly	12 – 650	144	29
	Rendall service station			16 – 610	149	29
	Covert			17 – 700	138	29
	Reactor site			18 – 730	143	30
					144	117
Deposition from precipitation: (pCi/m²-day)	South Haven		Weekly	24 –1,400	336	29
	Rendall service station			42 –1,100	317	29
	Covert			12 –1,300	326	29
	Reactor site			15 – 990	267	30
					312	117
Drinking water: (pCi/liter)	South Haven			3.1 – 5.1	3.4	
	St. Joseph			2.4 – 4.3	3.5	
	Benton Harbor			2.7 – 4.2	3.4	
Surface water: (pCi/liter)	Rogers Creek-Covert			ND–9	9	
	Black River-South Haven			ND	ND	
	Brandywine Creek-South Haven			ND–13	10	
	Lake Michigan-Benton Harbor			ND	ND	
	Lake Michigan-South Haven			ND–24	12	
	Lake Michigan-Bridgman			—	ND	
	St. Joseph River-St. Joseph			ND–10	9	
Plankton: (pCi/g)	Palisades Plant		1/annum		24.5	1
	Thirteenth Avenue	3 3/4 miles NNE			12.5	1
	Covert Park	4 3/4 miles SSE			24.5	1
					20.5	3
Shore minnows: (pCi/g)	Palisades Plant		1/annum		12.0	1
	Thirteenth Avenue				32.0	1
	Covert Park				13.0	1
					19.0	3
Filamentous algae: (pCi/g)	Palisades Plant		1/annum		120	1
	Thirteenth Avenue				30	1
					75	2

[a] Data from Michigan Department of Public Health.

Table 11. Preoperational surveillance data from Palisades nuclear power station, 1970[a]

Sample type	Type of measurement	Number of samples	Radioactivity	
			Mean	Range
Lake water: (pCi/liter)	Gross β	8	7.5	5 – 13
	Tritium	8	414	310 –600
Fish: (pCi/g)	Gross β	5	2.7	1.2 – 4.4
	Gross γ	5	.15	.04– 0.31
	^{90}Sr	5	.05	.02– .11
	^{137}Cs	5	.13	.08– .2
Milk: (pCi/liter)	^{137}Cs	16	1.9	.52– 7.0
	^{90}Sr	16	1.7	.87– 5.4
	^{3}H	4	[b]1.9	[b].81– 3.4
Air particulates: (pCi/m^3)	Gross β	35	.13	.04– .34
Fruits and berries: (pCi/g)	Gross β	15	2.54	.67– 2.7
	Gross γ	13	.20	.10– .28
Aquatic vegetation: (pCi/g)	Gross β	2	6	4 – 8
	Gross γ	2	1.7	1.4 – 2.1

[a] Data from Palisades Nuclear Power Station preoperational environmental radiation survey program summary report, May 28, 1971 by Consumers Power Company.
[b] Concentration, nCi/liter.

Table 12. Environmental radiation surveillance, Lake Michigan, July 1969–June 1970[a]

Sample type	Number of locations	Number of samples averaged	Analyses		Radioactivity		Average[b]
			Type	MDL	Minimum	Maximum	
Water	21	49	Zinc-65	8 pCi/liter	ND	32 pCi/liter	2.1 pCi/liter
			Cesium-137	3.5 pCi/liter	ND	9.5 pCi/liter	.63 pCi/liter
			Carbon-14				.2 pCi/liter
			Potassium-40				1.1 pCi/liter
			Radium-226				.03 pCi/liter
			Lead-210				.003 pCi/liter
			Tritium				560 pCi/liter
			Gross alpha				3.0 pCi/liter
			Gross beta (exclusive of ^{3}H)		1.3 pCi/liter	5.9 pCi/liter	[c]3.8 pCi/liter
Sediment: (1970)	43	53	Cesium-137	.1 pCi/g	ND	8.1 pCi/g	1.4 pCi/g
			Radium-226	[d]	0.4 pCi/g	4.6 pCi/g	1.6 pCi/g
			Potassium-40	[d]	5.0 pCi/g	30.0 pCi/g	15.0 pCi/g
Zooplankton: (ash weight)	21	59	Zinc-65	2.2 pCi/g	ND	95.5 pCi/g	2.3 pCi/g
			Cesium-137	1.0 pCi/g	ND	95.7 pCi/g	4.75 pCi/g
			Gross beta		5.2 pCi/g	162.2 pCi/g	58.2 pCi/g
Zooplankton: (wet weight)	21	59	Zinc-65	2.2 pCi/g	ND	1.2 pCi/g	.03 pCi/g
			Cesium-137	1.0 pCi/g	ND	3.2 pCi/g	.054 pCi/g
			Gross beta		.1 pCi/g	2.9 pCi/g	.725 pCi/g
Phytoplankton: (ash weight)	21	59	Zinc-65	2.2 pCi/g	ND	566.1 pCi/g	31.6 pCi/g
			Cesium-137	1.0 pCi/g	ND	6.4 pCi/g	.33 pCi/g
			Gross beta		16.1 pCi/g	119.1 pCi/g	36.9 pCi/g
Phytoplankton: (wet weight)	21	59	Zinc-65	2.2 pCi/g	ND	5.9 pCi/g	.96 pCi/g
			Cesium-137	1.0 pCi/g	ND	.7 pCi/g	.038 pCi/g
			Gross beta		.5 pCi/g	10.4 pCi/g	2.45 pCi/g
Benthos: (ash weight)	22	58	Zinc-65	2.2 pCi/g	ND	108.9 pCi/g	29.4 pCi/g
			Cesium-137	1.0 pCi/g	ND	20.2 pCi/g	2.86 pCi/g
			Gross beta		19.4 pCi/g	258.5 pCi/g	108.9 pCi/g
Benthos: (wet weight)	22	58	Zinc-65	2.2 pCi/g	ND	27.8 pCi/g	.89 pCi/g
			Cesium-137	1.0 pCi/g	ND	.5 pCi/g	.079 pCi/g
			Gross beta		.1 pCi/g	39.7 pCi/g	3.77 pCi/g
Fish:[e] (ash weight)	7	7	Zinc-65	2.2 pCi/g	ND	31.7 pCi/g	12.8 pCi/g
			Cesium-137	1.0 pCi/g	ND	29.9 pCi/g	8.66 pCi/g
			Gross beta		81.9 pCi/g	107.3 pCi/g	93.8 pCi/g
Fish: (wet weight)	7	7	Zinc-65	2.2 pCi/g	ND	1.0 pCi/g	.42 pCi/g
			Cesium-137	1.0 pCi/g	ND	.92 pCi/g	.36 pCi/g

[a] Data from University of Michigan study.
[b] Mean values based on <MDL (minimum detectable level) taken as zero. Averages for long-lived radionuclides would consequently tend to be low.
[c] It is considered that less than 2 pCi/liter of gross beta activity in Lake Michigan water is attributable to radioactivity of natural origin (4).
[d] All radium-226 and potassium-40 levels were significant; hence determination of MDL was unnecessary.
[e] A sample of perch (edible flesh, wet weight) taken at Big Rock Point showed the following values: cesium-137, 0.92 pCi/g; zinc-65, 0.24 pCi/g. ND, below detectable limits (<MDL), corrected for decay back to June 15, 1969.

Michigan under a contract with a consortium of utility companies. Media surveyed were water, bottom sediment, plankton, benthic organisms, and fish (*4*). Samples were taken at grid locations along five tracks approximately equally spaced over the lake. Data developed in the course of this survey are presented in table 12 and are not inconsistent with the Argonne data shown in table 6.

Inspection of the values for samples taken from areas of the lake near the Big Rock Point Plant revealed no substantial deviations from the averages for the lake as a whole. Accordingly, a separate tabulation has not been provided for that area. This is in contrast to the data obtained by Argonne and presented in tables 5, 6, and 7. Argonne performed intensive sampling within 3 miles of the site. The closest sample point used for the University of Michigan study was 1 mile from the site of Big Rock Point discharges.

Summary of surveillance activities

Environmental radiation from various sources and media have been measured in the State of Michigan. A summary of available data is presented in table 13. It has not been possible to acquire all the specific data that may be required to construct an accurate estimate of the radiation exposure of the population of Michigan, or any given portion of this population. Nevertheless, some broad perspectives can be gained, particularly with respect to the major sources of exposure.

It may be noted that the gross beta radioactivity in air is of the same general magnitude for the vicinity of the Big Rock Point plant as for the vicinity of the Palisades plant, a control site at a distance from any operating reactor. Also, data for precipitation do not indicate any need to consider this source as applicable to special problems related to existing nuclear power operations.

Although radioactivity in Lake Michigan water (table 12) may not reflect the true situation with respect to the public drinking water supplies, the gross beta radioactivity is well within the PHS drinking water standard of 1,000 pCi/liter, taking into account the small amounts of radium and strontium-90 present.

The 1970 average values for strontium-90 and cesium-137 in milk are close to those for the EPA Pasteurized Milk Network stations and State stations. A listing of the individual stations in the State would show variations among the stations at least equal in magnitude to the deviation of the State average from the Pasteurized Milk Network average, as may be seen in table 14 for the 12-month State average.

Although the Charlevoix area, which is near the Big Rock Point plant, showed somewhat higher values than the State average, no conclusion can be drawn from this finding. Marquette, which is on Lake Superior and far removed from any nuclear power plant, showed even higher values.

In the absence of a diet surveillance program within the State, it may be of interest to consider data from the institutional diet sampling program conducted jointly by EPA and the Food and Drug Administration. Cleveland, Ohio, the sampling location nearest to Michigan, showed 1970 dietary intake values for strontium-90 and cesium-137 of 11 and 10 pCi per day, respectively (*8*). This compares with the national network averages of 10 and 11 pCi per day for strontium-90 and cesium-137, respectively. Since the daily intake for strontium-90 and cesium-137 is approximately equal to that contained in a liter of milk, it seems reasonable to assume, for purposes of dietary intake calculations, that if we take the value for intake of a liter of milk per day, we can approximate the average daily total dietary intake of these radionuclides.

The data for background terrestrial radiation dose in table 13 were derived by taking measurements at some distance from manmade structures (*7*). The effects of proximity of manmade structures and variations in indoor environments are not considered in the tabulation. The values for terrestrial and cosmic radiation dose agree with those published by Solon et al. (*9*) and by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (*10*) for cosmic radiation dose. Both the State of Michigan and Consumers Power Company report no detectable gamma dose above background from their TLD

Table 13. Michigan surveillance programs

Media sampled	Location (number of sites)	Collection frequency	Number of samples	Type of analyses	Radioactivity	
					Mean	Range
Air:	(14)	Weekly		Gross beta		
(reactor-oriented)	Big Rock (5)		250		0.252	0.059– 0.94
(pCi/m³)	Fermi (4)		177		.234	.053– .75
	Palisades (4)		158		.267	.059– .92
	Lansing (1)[a]		51		.206	.035– .66
Precipitation:	(14)	Weekly		Gross beta		
(reactor-oriented)	Big Rock (5)		91		32.8	.17 –130
(pCi/liter)	Fermi (4)		109		85.6	9.1 –605
	Palisades (4)		117		144.0	12.0 –730
	Lansing (1)[a]		29		130.0	16.0 –920
Deposition:	(14)	Weekly		Gross beta		
(reactor-oriented)	Big Rock (5)		91		8.65	.15 – 28
(fCi/m²-day)	Fermi (4)		109		17.5	1.5 – 58
	Palisades (4)		117		31.2	1.2 –140
	Lansing (1)[a]		29		29.1	2.2 –130
Water: (pCi/liter)						
Lake Michigan	See table 11 for data other than strontium-90					
	Various depths		9	Strontium-90[b]	.6	
Drinking water: (pCi/liter)	Throughout State	Quarterly or semiannually	107	Gross beta	3.1	<.94 – 8.4
Surface water: (pCi/liter)	Throughout State	Quarterly or semiannually	137	Gross beta	<8.2	<8.2 – 28
Milk: (ref. 6)		Monthly				
PMN	(2)			Strontium-90	9.2	
State network	(8)			Cesium-137	11.0	
Natural background terrestrial: (ref. 7)	(23)			Gamma	7.8 μrad/h 70 mrad/a	6.6 – 9.2 μrad/h
Cosmic radiation: (based on average inhabitant elevation = 600 feet)	Statewide				4.1 μrad/h 36 mrad/a	

[a] Lansing: control surveillance station.
[b] Extrapolated from reference (5).

Table 14. 12-month average of radionuclide concentrations in milk, 1970

Station	Concentrations (pCi/liter)	
	Strontium-90	Cesium-137
Detroit[a]	9	9
Grand Rapids[a]	9	12
Bay City	7	11
Charlevoix[b]	13	16
Detroit	8	8
Grand Rapids	9	8
Lansing	9	14
Marquette	14	23
Monroe	6	3
South Haven	8	6
Average	9	11

[a] EPA Pasteurized Milk Network station.
[b] Area of Big Rock Point Plant. Other stations are part of Michigan Department of Health network.

and film badge readings at offsite locations near Big Rock Point nuclear power station.

In addition to the foregoing sources of radiation exposure, the State of Michigan reported, for fiscal 1970, three operable nuclear reactors (non-power); 465 licenses for by-product, source, and special nuclear materials; 130 registered facilities for the use of radium or radon; and 30 particle accelerators (*11*). The State also has regulatory legislation with respect to x-ray machines, of which there were 4,078 dental, 4,330 medical (including 265 therapeutic), and 170 industrial x-ray machines registered (*11*).

Dose assessment of Michigan population

Table 15 presents a summary of estimated annual radiation doses to the population from all identified sources. Included is the special case of doses to the population in the vicinity of

Big Rock Point. Doses from the lesser contributory sources are included for perspective. Totals given as ranges are rounded to two significant figures, as warranted by the limitations of the estimates.

The data for external background gamma radiation (*7*) are not intended to represent average radiation levels for exposure of the State's population, since the areas surveyed were not randomly selected, nor were they spaced with the idea of developing contour lines. Nevertheless, the data are made from determinations within the State, and may be considered as providing a reasonable estimate. Of the reactor sites, only the South Haven (Palisades) area was monitored. The average background gamma radiation level at this location was 7.3 μR/hr, which was below the average for the State measurements.

The value given for cosmic radiation is probably on the low side, since it assumes an elevation of 600 feet above sea level. Lake Michigan itself is at an elevation of 581 feet, while the average elevation of the State is 900 feet (*14*). Reactor sites on Lake Michigan and Lake Erie (elevation 572 feet) would probably be at altitudes of close to 600 feet.

The genetically significant dose (GSD) of 55 mrem/a from medical diagnostic x-rays was taken from the 1964 national survey (*15*). The radiation dose figures from occupational and miscellaneous sources are admittedly out-of-date, and may be lower in Michigan than those given in table 15, particularly the value for GSD from occupational exposure. Factors that are expected to contribute to occupational exposure are the growth in nuclear medical procedures and research, growth in industrial use of x-rays, and radionuclides in materials analysis and processing. However, industrial use of ionizing radiation in Michigan has declined approximately 30 percent from 1965 to 1970.[4]

Dose related to nuclear power operations

As mentioned, Big Rock Point is the only nuclear power facility in Michigan which operated during the entire year of 1970. It, therefore, represents the source of maximum population dose resulting from nuclear power facility effluents. Because of background radiation, the contribution of radionuclides from the reactor released to the environment cannot be precisely distinguished. Nevertheless, some idea of the magnitude of population dose from this source may be obtained by using one of the following approaches.

Dose from external radiation A special study (*16*) performed around the Dresden Nuclear Power Station in Illinois—a facility with gaseous effluents similar to those at Big Rock Point—determined that the only measurable population dose attributable to plant effluents, was due to external radiation from noble gases discharged to the atmosphere. These measurements indicated that the maximum dose to an individual member of the public in the vicinity of the Dresden plant would be in the range of 5 to 15 millirem per year.

Gamertsfelder (*17*) has made calculations of population dose around operating nuclear facilities based on discharges and environmental conditions. His calculations indicate a dose from all exposure pathways of 18 millirem per year at the boundary of the Dresden plant during 1969. This agrees with the values based on the 1968 special study (*16*) mentioned above, when the gaseous discharges were one-third as high as in 1969. Such agreement tends to support the accuracy of the calculated dose. Gamertsfelder's calculations of population dose from Big Rock Point waste discharges indicate a maximum dose of 3.25 millirem per year at the plant boundary, and an average dose within a 50-mile radius from the plant of 0.065 millirem per year.[5] One could not expect to measure this level of population exposure in the environment in the presence of the other sources of higher exposure. This is partially confirmed by the data (table 13) for air and precipitation which show no higher levels near Big Rock Point than at other locations.

[4] Personal communication from Mr. D. E. Van Farowe, chief, Division of Radiological Health, State of Michigan Department of Public Health.

[5] R. W. Sunderman, health physicist, Consumers Power Company (personal communication) points out that these dose calculations are high by a factor of 2.4.

Table 15. Estimated annual radiation doses[a] to general population, Michigan

Source of radiation	Dose (mrem/a)	Remarks
Natural radiation (external):		
Terrestrial gamma rays	60 – 85	Reference (7)
Cosmic rays	35 – 50	Based on UNSCEAR (*10*) and special studies[b]
Natural radiation (internal sources):		
Potassium-40	17	Special studies[b]
Carbon-14	.7	To gonads; 1.6 to bone marrow (10)
Radium-226, radium-228 and progeny	.6	To gonads; 0.7 to bone marrow (10)
Subtotal (rounded)	113 –153	
Residual fallout from nuclear tests[c] as source:		
Cesium-137	1.2	Based on 0.3 mrad following intake of 1 nanocurie from 360 liters of milk/a
Strontium-90	.25	To bone marrow, based on FRC Report No. 2 (*12*), assuming average intake of 1 g calcium/day
Carbon-14	.7	Computed from dose commitment data in UNSCEAR (*10*)
Tritium	.001	
Subtotal	2.0	
Medical radiation x rays:		
X rays, diagnostic	55	Genetically significant dose (GSD) (see text)
Radiation, therapeutic x and gamma rays	5	GSD, estimated[d]
Radiopharmaceuticals, therapeutic	.6	GSD, estimated[d]
diagnostic	.6	
Occupational	~1	Average dose to U.S. population[b]
Other (luminous dials, TV, etc.)	2	GSD, estimated (*13*)
Subsotal	64	
Total (rounded)	180 –220	
Residents, Big Rock Point vicinity:		
External	.065	Average, 50-mile radius from plant
Internal (ingestion)	~1	(See text)

[a] Dose to gonads and other soft tissues, except where otherwise stipulated.
[b] Special Studies Group, Division of Criteria and Standards, Office of Radiation Programs, EPA. Estimates of ionizing radiation doses in the United States, 1960–2000 (in press).
[c] Strontium-89, iodine-131, and other short-lived radionuclides are considered to have decayed to zero.
[d] Dr. B. Shleien, personal communication, based on data for 1966.

Dose from ingested radionuclides A somewhat oblique approach to dietary intake of radioactivity is attempted to provide some idea of the possible contribution of diet to dose. In the absence of data on radioactivity in and consumption of local game and other animals, or of vegetable produce or other local foods, an admittedly high intake of fish taken in the vicinity of the plant is assumed. An intake of 100 grams per day of fish taken from the vicinity of the outfall of the Big Rock Point plant (average values from table 7 divided by 4 to compensate for dry weight) is assumed in our calculations. The formula used is adapted from the method of Weaver (*18*), and is based on a summation of intakes of each radionuclide as a fraction of the Radiation Protection Guide (RPG) for a member of the general population. The formula is:

$$\frac{I_A}{\text{guide A}} + \frac{I_B}{\text{guide B}} + \frac{I_C}{\text{guide C}} \ldots = F_{RPG}$$

where I_A, I_B, I_C, etc., are intakes (pCi/day) of the individual radionuclides, and F_{RPG} is the fraction of the RPG for the sum of the nuclides.

The radionuclides determined in this case are cesium-134, cesium-137, zirconium-95, zinc-65, and cobalt-60. Application of the average values for these nuclides from table 7, adjusted for wet weight concentrations, gives:

$$\frac{17.5}{20{,}000} + \frac{84}{45{,}000} + \frac{2.7}{130{,}000} + \frac{730}{220{,}000} + \frac{11}{110{,}000} = 0.0062^{e}$$

[e] These calculations do not make allowance for the functional contribution of cesium-137 from fallout. D. M. Nelson (personal communication) indicates that this contribution is about one-half of the total for this radionuclide.

Thus, on the basis of conservative (and probably pessimistic) premises both for consumption and site of capture of the fish, the radioactivity intakes amount to 3.3 millirem per year or less than 1 percent of the radiation protection guide of 500 mrem. If an average annual population consumption of 8 kilograms of fresh fish, as estimated for the United States (*19*), is assumed, the dose would be less than 1 millirem per year.

Discussion

The first report of surveillance activities in the State of Michigan shows that at least one nuclear facility is discharging sufficient radioactive material to be detected in the environment. However, the resulting dose to the population is insignificant in comparison to the dose from other sources. The maximum dose to a hypothetical individual from a nuclear facility's discharges is only a gross estimate. Participation in the National Environmental Radiation Monitoring Program by monitoring agencies in the State and more detailed reporting of discharges by nuclear facility operators as proposed by the Atomic Energy Commission should result in more usable data for dose calculations in the future.

Acknowledgements

Appreciation is expressed to the following for their assistance in supplying data and their constructive suggestions on this report. D. E. Van Farowe, chief, Division of Radiological Health, State of Michigan Department of Health; Professor G. H. Whipple, Department of Environmental and Industrial Health, University of Michigan; R. W. Sinderman, health physicist, Consumers Power Company; and J. Feldes, Detroit Edison Company.

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A Summary of Environmental Radiation Surveillance Activities in Arkansas

Burvie H. Sheets, William H. Oates, Jr., David D. Snellings, Jr., and E. Frank Wilson[1]

This report describes the environmental radiation surveillance program of the Division of Radiological Health, Arkansas State Department of Health. The program has been broken into two general categories: (1) statewide system and (2) source-oriented surveillance activities. There are two nuclear facility sites in Arkansas and extensive surveillance activities are presently being conducted near each site. Some of the data that were collected during 1966 through 1970 are presented.

The State Department of Health was designated the responsible agency within the State of Arkansas for the evaluation and control of radiation hazards by Act 8 of the Second Extraordinary Session of the Arkansas Legislature of 1961. One of the methods used in assessing radiation hazards is a continuing environmental radiation surveillance program. The purpose of this report is to provide a general description of this surveillance program and a summary of data that has been collected for the period 1966 through 1970. The radiation surveillance program in Arkansas can be divided into three categories:

1. State,
2. Southwest Experimental Fast Oxide Reactor (SEFOR), and
3. Arkansas Nuclear One Reactor (AN–1).

The State program was established during 1956 as a result of atmospheric nuclear weapons testing. This program consists of:

1. Monthly analyses of milk samples which are collected from representative processing plants throughout the state,
2. Analyses of precipitation collected at the State Department of Health Building in Little Rock, and
3. Participation in the Radiation Alert Network air sampling program of the Environmental Protection Agency by operating the Little Rock station.

Both the SEFOR and the Arkansas Nuclear One programs are source-oriented surveillance activities. The SEFOR program consists of the collection and analysis of milk and other environmental samples in the offsite environs of the Southwest Experimental Fast Oxide Reactor (SEFOR) located 20 miles southwest of Fayetteville, Ark. The Arkansas Nuclear One (AN–1) program is currently a preoperational project conducted in the vicinity of the construction site for Arkansas Power and Light Company's (AP&L) first nuclear power reactor. This pressurized water reactor (PWR) will be located approximately 6 miles west of Russellville, Ark., on the Dardanelle Reservoir.

Analytical methods

Environmental samples are prepared and analyzed for radioactive materials using gamma scintillation and proportional counting equipment. The objectives of the surveillance programs require both the qualitative and quantitative analysis of radionuclides present. For source-oriented surveillance activities, the radionuclides to be evaluated are specified early in the system planning phase as a portion of the public health evaluation. The necessary equipment and procedures are then established to perform the required identification and measurements.

[1] Mr. Wilson is the director, Mr. Snellings is the assistant director and Messrs. Oates and Sheets are staff members of the Division of Radiological Health, Arkansas State Department of Health, Little Rock, Ark. 72201.

Total sample analysis is performed by spectral analysis and/or radiochemistry techniques. Gamma spectroscopy is a relatively simple laboratory procedure; however, detailed standardization methods and mathematical analyses are necessary to evaluate the resultant data. Radiochemistry is a more complex and time-consuming method but is necessary for the separation and analysis of non-gamma-emitting radionuclides.

Gamma scintillation methods are used to simultaneously quantitate the following radionuclides:

Cerium–144	Thorium–232
Iodine–131	Zinc–65
Ruthenium–106	Potassium–40
Cesium–137	Barium–140
Zirconium–95	Bismuth–214
Manganese–54	

This type analysis, which is routinely performed on those samples listed in tables 1 and 2, involves no radiochemical reduction but is a direct evaluation of the raw sample. Resultant data are then compiled into a series of simultaneous equations which are solved by the matrix method. This method utilizes the photopeak areas of the sample spectrum and involves solving simultaneous equations to correct for the interference of one radionuclide in the peak of another. Computer techniques are used to solve the equations and also correct for the radioactive decay and the detector efficiency for each radionuclide.

Table 1. Environmental surveillance program at the SEFOR nuclear reactor

Type of sample	Relative sampling frequency	Type of analysis
Surface water	Quarterly	Gamma scan, gross alpha and beta
Silt	Quarterly	Gamma scan, gross alpha and beta
Grass	Quarterly	Gamma scan, gross alpha and beta
Soil	Quarterly	Gamma scan, gross alpha and beta
Milk	Monthly	Gamma scan
Air	Biweekly	Gamma scan, gross beta

Radiostrontium is chemically extracted from milk samples under laboratory conditions using the methods described by Porter et al. (*1*). The strontium is then analyzed in a low-background beta counter. After a suitable daughter in-

Table 2. Preoperational environmental surveillance program at Arkansas Nuclear One

Type of sample	Relative sampling frequency	Type of analysis
Surface water	Semiannually	Gamma scan, gross alpha and beta, tritium
Silt	Semiannually	Gamma scan, gross alpha and beta
Grass	Semiannually	Gamma scan, gross alpha and beta
Soil	Semiannually	Gamma scan, gross alpha and beta
Aquatic biota	Semiannually	Gamma scan, gross beta
Milk	Quarterly	Gamma scan

growth period and subsequent measurements, final calculations are performed to determine the quantity of radiostrontium in the milk.

Gross alpha and beta analysis, using internal proportional counting techniques, are performed on selected samples as shown in tables 1 and 2. Because proper detection equipment is not available within the State, an agreement was made with the Environmental Protection Agency's Eastern Environmental Radiation Laboratory to perform tritium analysis of the surface water samples from the AN–1 environs.

Before environmental samples are counted, a minimum detectable activity (MDA) is determined. If the activity of the sample is not equal to or greater than the MDA, the analytical results are reported as being less than the MDA. For determining yearly averages, the monthly averages not exceeding the MDA are considered to be zero.

Statewide surveillance program

The sampling stations for pasteurized milk, shown in figure 1, were chosen because of their proximity to milk production and distribution centers. Samples are collected on a monthly basis and are analyzed for gamma-emitting radionuclides, strontium-89 and strontium-90. Several stations in the statewide milk system are included in the Standby Milk Surveillance Network of the Environmental Protection Agency's Western Environmental Research Laboratory.

Figures 2 and 3 show the average monthly concentrations for iodine-131 and cesium-137 in milk for 1966 through 1969. The program was terminated in 1970 but was started up again in 1971. Also, no samples were collected during the last 3 months in both 1967 and 1968. In

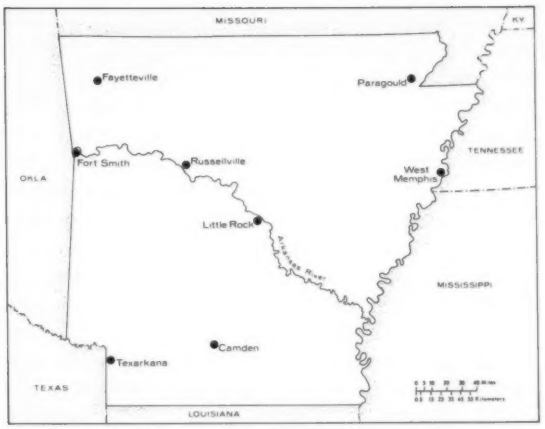

Figure 1. State Pasteurized Milk Network

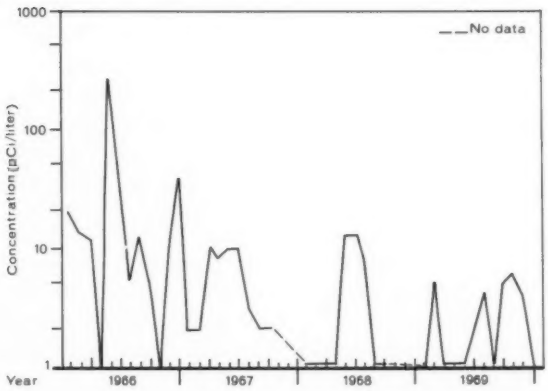

Figure 2. Average monthly iodine-131 concentration in pasteurized milk for all stations in State programs, 1966–1969

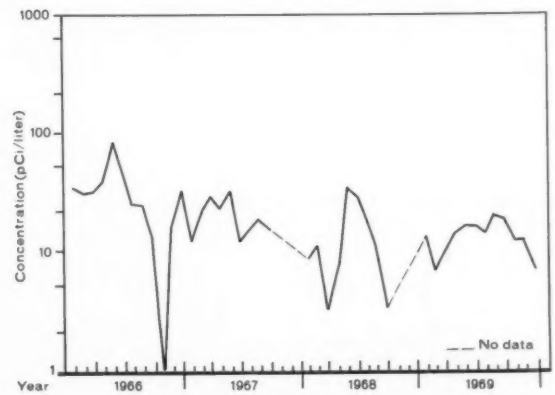

Figure 3. Average monthly cesium-137 concentration in pasteurized milk for all stations in State programs, 1966–1969

order to use semilog graph paper and simplify presentation of data, all monthly averages that were equal to zero or were less than the MDA have been plotted as a value of one. The peak values in 1966 are apparently due to the atmospheric testing of a nuclear device in China during April of that year (*2*). Figure 4 shows the average yearly concentrations in milk for cesium-137, iodine-131, barium-140, and total potassium. Because of the more lengthy analytical process for strontium-89 and strontium-90 determinations and the large number of samples, very little data are available for these two radionuclides in this part of the surveillance program.

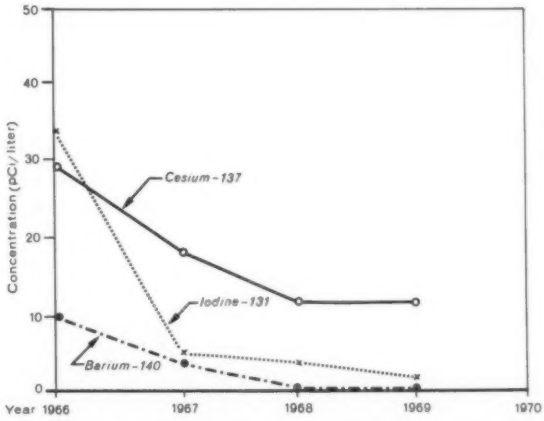

Figure 4. Average yearly concentration of selected radionuclides in pasteurized milk for all stations for all stations in State programs, 1966–1969

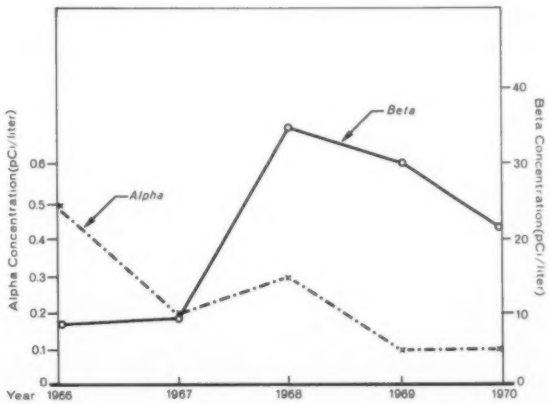

Figure 5. Average yearly gross alpha and beta concentration in precipitation at Little Rock, Ark., 1966–1970

Precipitation samples, both rain and snow, are collected and analyzed for gross alpha and beta radioactivity. Figure 5 depicts the yearly averages for gross alpha and beta radioactivity in precipitation for 1966 through 1970.

The air analysis data from Little Rock are not presented in this report since they are routinely published by the Environmental Protection Agency in *Radiation Data and Reports.*

Nuclear facilities environmental surveillance programs

In the late 1950's and early 1960's, the primary emphasis in environmental radiation surveillance was on statewide and/or nationwide programs. However, the moratorium on atmospheric nuclear tests following the signing of the Test Ban Treaty of 1963 has decreased the need for large area surveillance programs. The expanding use of nuclear power for electrical generating plants has resulted in both State and Federal Public Health Agencies increasing their responsibilities in surveillance of nuclear power plants and other nuclear facilities. In the context of this new emphasis in surveillance, the Division of Radiological Health is presently conducting, as has been previously noted, two source oriented programs: (1) an operational program at the SEFOR plant near Fayetteville, Ark., and (2) a preoperational program near Russellville, Ark., for AN–1. The surveillance activities by the Division of Radiological Health are conducted only in locations external to the facility's fenced area.

The prime objectives of environmental surveillance programs for nuclear facilities are (1) to verify the adequacy of source control, (2) to provide a source of data for public information, and (3) in certain situations, to provide data for estimating population doses.

SEFOR reactor

The SEFOR reactor near Fayetteville became operational during the first week of May 1969. In order to obtain reliable baseline data, a preoperational surveillance program

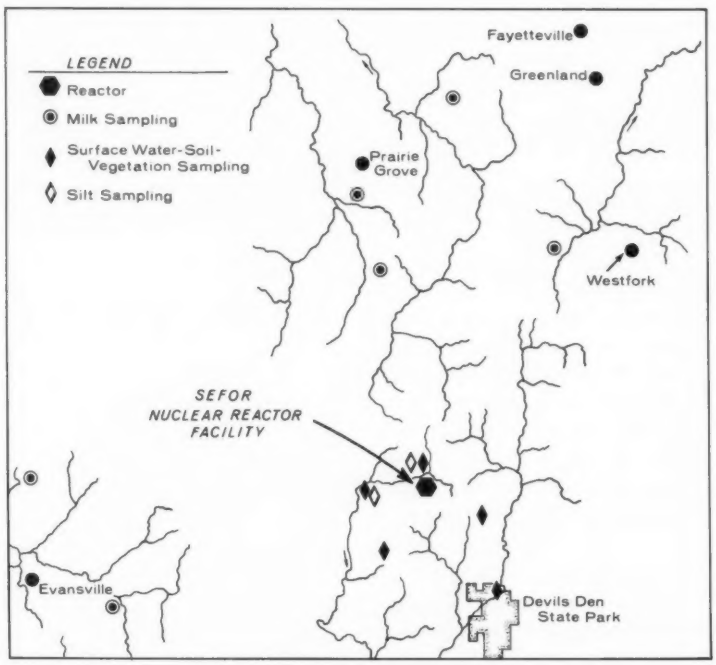

Figure 6. Environmental surveillance sampling locations at the SEFOR facility

was conducted for 2 years prior to reactor startup. Table 1 shows the operational phase system as it now exists while figure 6 shows the location of sampling stations. Since the production of milk in the reactor environs is limited, only a small number of sampling locations have been established.

Fall Creek, which is the main hydrological feature of the area, flows eventually into the Van Buren, Ark., public water supply. While the facility does not discharge liquid waste directly to Fall Creek, laundry wastes may reach the stream after migration through the facility's tile field. Therefore, sampling stations were established to monitor the possible low-level liquid effluents.

Figure 7 shows the average yearly iodine-131 and cesium-137 concentrations in the milk samples collected in the SEFOR environs for 1966 through 1970. As can readily be seen, the concentrations in milk for both of these radionuclides have decreased considerably since 1966. The principal reason for the high averages during 1966 was apparently a result of a multiple deposition of radioactive material on Northwest Arkansas from an atmospheric nuclear weapon detonated on the Chinese mainland during April of that year (*2*). Figure 8 shows the monthly averages for gross beta radioactivity contained in air samples collected at SEFOR from the middle of 1967 through 1970. The fluctuation in the measurements of these samples compared favorably to the fluctuation in the data for the Little Rock station of the Radiation Alert Network of the Environmental Protection Agency for the same period of time. Tables 3 and 4 summarize the analytical results of the environmental samples collected in the SEFOR environs during 1969 and 1970, respectively.

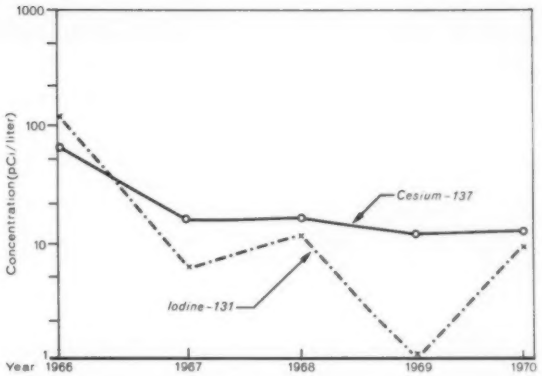

Figure 7. Average yearly cesium-137 and iodine-131 concentrations in raw milk from SEFOR sampling locations, 1966–1970

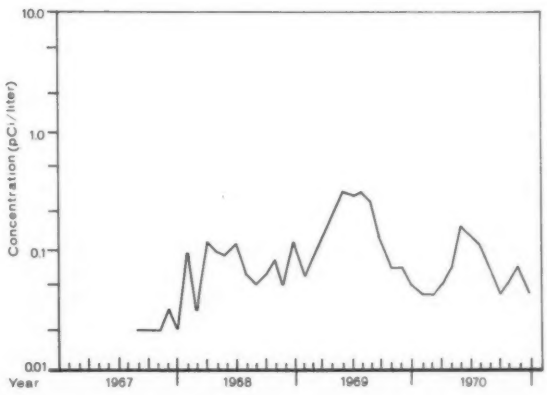

Figure 8. Average monthly gross beta concentration in air from SEFOR sampling location, 1967–1970

Table 3. Average radioactivity in environmental samples at SEFOR, 1969[a]

Type of sample	Number of samples	Average radioactivity concentration[b]													
		^{144}Ce	^{131}I	^{106}Ru	^{137}Cs	^{95}Zr	^{54}Mn	^{232}Th	^{65}Zn	^{140}Ba	^{214}Bi	^{89}Sr	^{90}Sr	Gross alpha	Gross beta
Milk (pCi/liter)	9	NA	1	NA	8	NA	NA	NA	NA	0.4	NA	0	11	NA	NA
Surface water (pCi/liter)	4	0	0	0	0	0	0	0	0	0	0	NA	NA	NA	NA
Silt (pCi/g dry weight)	4	0	0	0	0	0	0	.3	0	0	0	NA	NA	6	7
Grass (pCi/g dry weight)	4	1	0	5	1	2	.1	NA	0	0	NA	NA	NA	11	284

[a] No soil or aquatic biota samples were taken during this period.
[b] Zero indicates that sample average is equal to or less than the MDA.
NA, no analysis.

Table 4. Average radioactivity in environmental samples at SEFOR, 1970[a]

Type of sample	Number of samples	Average radioactivity concentration[b]													
		^{144}Ce	^{131}I	^{106}Ru	^{137}Cs	^{95}Zr	^{54}Mn	^{232}Th	^{65}Zn	^{140}Ba	^{214}Bi	^{89}Sr	^{90}Sr	Gross alpha	Gross beta
Milk (pCi/liter)	11	NA	10	NA	13	NA	NA	NA	NA	5	NA	NA	NA	NA	NA
Surface water (pCi/liter)	6	10	0	0	0	0	0	0	0	0	0	NA	NA	0	1
Soil (pCi/g dry weight)	5	2	1	1	0.4	0.3	0	0.6	0	0	1	NA	NA	8	27
Grass (pCi/g dry weight)	1	2	0	5	.4	7	0	NA	0	0	NA	NA	NA	NA	NA

[a] No silt or aquatic biota samples were taken during this period.
[b] Zero indicates that sample average is equal to or less than the MDA.
NA, no analysis.

In summary, the Division of Radiological Health has conducted an environmental surveillance program at the SEFOR facility for approximately 5 years. This period of time spans both the preoperational and operational phases of this research reactor. In comparing preoperational and operational surveillance data it can be concluded that SEFOR has not produced a measurable increase in the environmental radioactivity level of its environs.

Arkansas Nuclear One

The surveillance system surrounding the Arkansas Nuclear One (AN–1) site is a comprehensive network typical of other PWR surveillance systems. The area surrounding the plant site is used for agricultural, recreational, and residential purposes. The Dardanelle Reservoir (Arkansas River) is not used as a potable water supply; however, commercial and sport fishing on the reservoir, as well as other water recreation activities, appear to be potential exposure pathways to man. Sampling locations of surface waters, as well as other sample types are shown in figure 9 and are listed, along with the sampling frequencies in table 2.

As noted in the public health evaluation (*3*), milk is one of the prime exposure pathways to man and has been given emphasis in the AN–1 preoperational program consistent with the availability of sampling locations. Since the inception of the surveillance network, several dairymen in the area directly east of the site (vicinity of Atkins) have ceased operations. These dairies had been previously selected as sampling stations, which explains the void in the area coverage as shown in figure 9.

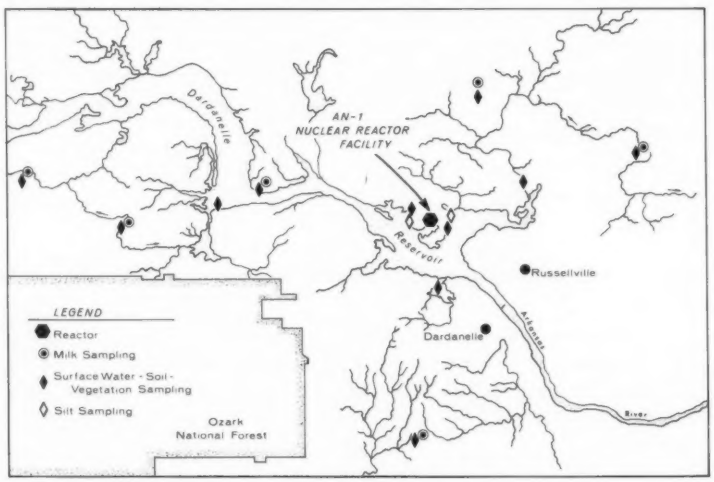

Figure 9. Environmental surveillance sampling locations at the AN–1 facility

A review of the preoperational program is conducted on an annual basis and is designed to update the system to insure that the most sensitive vectors are included. The early initiation has also insured the availability of reliable baseline data and that the objectives of the surveillance program will be met.

Tables 5 and 6 summarize the analytical results of the environmental samples collected at AN–1 during 1969 and 1970, respectively. The operational surveillance program at AN–1 will be essentially the same as the preoperational program except for a difference in sampling frequency. For example, samples that are now collected quarterly will be collected monthly and those now collected semiannually will be collected and analyzed quarterly.

Summary and conclusions

A discussion has been given on the environmental radiation surveillance programs in Arkansas and some of the data that was collected during 1966 through 1970 have been presented. While a statewide milk surveillance network will be maintained in the future, the primary emphasis will be on nuclear facility offsite surveillance activities. The possibility of the effluent releases from the SEFOR nuclear plant adversely affecting the general public is quite small. This is due not only to the design of the SEFOR facility but also to the reactor's geographic location. However, the experience gained in source-oriented surveillance activities at this nuclear facility has been beneficial in establishing and operating the surveillance program at Arkansas Nuclear One. The recent controversies on the potential hazards of nuclear reactors and the new proposed AEC regulations that will reduce the discharge limits of light water nuclear power plants (*4*) have increased the importance of the data that will be collected at Arkansas Nuclear One.

REFERENCES

(*1*) PORTER, C. R., B. KAHN, M. W. CARTER, G. L. REHNBERG, and E. W. PEPPER. Determination of radiostrontium in food and other environmental samples. Environ Sci Technol 1:745–750 (September 1967).

(*2*) STRONG, A. B., C. R. PORTER, M. W. CARTER, and E. F. WILSON. The localization of fallout in the United States from May 1966 Chinese nuclear test. Public Health Rep 82:487–495 (June 1967).

Table 5. Average radioactivity in environmental samples at Arkansas Nuclear One, 1969

Type of sample	Number of samples	Average radioactivity concentration													
		^{144}Ce	^{131}I	^{106}Ru	^{137}Cs	^{95}Zr	^{54}Mn	^{232}Th	^{65}Zn	^{140}Ba	^{214}Bi	^{89}Sr	^{90}Sr	Gross alpha	Gross beta
Milk (pCi/liter)	15	NA	5	NA	20	NA	NA	NA	NA	4	NA	8	21	NA	NA
Surface water (pCi/liter)	19	0	0	0	1	1	0	0	0	0	8	NA	NA	0	2
Soil (pCi/g dry weight)	4	0	0	1	1	1	0	1	0	0	1	NA	NA	0	14
Silt (pCi/g dry weight)	4	0	0	.4	.3	.5	0	1	0	0	1	NA	NA	0	13
Grass (pCi/g dry weight)	4	0	0	3	.2	3	0	NA	0	0.1	NA	NA	NA	0	237

NA, no analysis.

Table 6. Average radioactivity in environmental samples at Arkansas Nuclear One, 1970

Type of sample	Number of samples	Average radioactivity concentration													
		^{144}Ce	^{131}I	^{106}Ru	^{137}Cs	^{95}Zr	^{54}Mn	^{232}Th	^{65}Zn	^{140}Ba	^{214}Bi	^{89}Sr	^{90}Sr	Gross alpha	Gross beta
Milk (pCi/liter)	14	NA	4	NA	15	NA	NA	NA	NA	0	NA	NA	NA	NA	NA
Surface water (pCi/liter)	16	0	5	0	3	0	0	0	1	1	0	NA	NA	0	8
Soil (pCi/g dry weight)	6	2	11	.5	.5	0.4	0	1	0	0	1	NA	NA	8	29
Silt (pCi/g dry weight)	8	2	17	.4	.2	.2	0	.5	0	1	1	NA	NA	9	36
Grass (pCi/g dry weight)	2	2	NA	4	4	8	0	NA	0	.1	NA	NA	NA	NA	NA

NA, no analysis.

(3) U.S. PUBLIC HEALTH SERVICE. Public health evaluation—Russellville nuclear power station, NF–68–15. Environmental Surveillance and Control Program, National Center for Radiological Health, Department of Health, Education and Welfare, Rockville, Md. 20852 (June 1968).

(4) U.S. ATOMIC ENERGY COMMISSION. Proposed rulemaking. Licensing of production and utilization facilities, light-water-cooled nuclear power reactors. Federal Register 10 CFR, Part 50, 36: 11113–11117. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (June 9, 1971).

Data

SECTION I. MILK AND FOOD

Milk Surveillance, September 1971

Although milk is only one of the sources of dietary intake of environmental radioactivity, it is the food item that is most useful as an indicator of the general population's intake of radionuclide contaminants resulting from environmental releases. Fresh milk is consumed by a large segment of the population and contains several of the biologically important radionuclides that may be released to the environment from nuclear activities. In addition, milk is produced and consumed on a regular basis, is convenient to handle and analyze, and samples representative of general population consumption can be readily obtained. Therefore, milk sampling networks have been found to be an effective mechanism for obtaining information on current radionuclide concentrations and long-term trends. From such information, public health agencies can determine the need for further investigation or corrective public health action.

The Pasteurized Milk Network (PMN) sponsored by the Office of Radiation Programs, Environmental Protection Agency, and the Office of Food Sanitation, Food and Drug Administration, U.S. Public Health Service, consists of 63 sampling stations: 61 located in the United States, one in Puerto Rico, and one in the Canal Zone. Many of the State health departments also conduct local milk surveillance programs which provide more comprehensive coverage within the individual State. Data from 15 of these State networks are reported routinely in *Radiation Data and Reports*. Additional networks for the routine surveillance of radioactivity in milk in the Western Hemisphere and their sponsoring organizations are:

Pan American Milk Sampling Program (Pan American Health Organization and U.S. Environmental Protection Agency)—5 sampling stations

Canadian Milk Network (Radiation Protection Division, Canadian Department of National Health and Welfare)—16 sampling stations.

The sampling locations that make up the networks presently reporting in *Radiation Data and Reports* are shown in figure 1. Based on the similar purpose for these sampling activities, the present format integrates the complementary data that are routinely obtained by these several milk networks.

Radionuclide and element coverage

Considerable experience has established that relatively few of the many radionuclides that are formed as a result of nuclear fission become incorporated in milk (*1*). Most of the possible radiocontaminants are eliminated by the selective metabolism of the cow, which restricts gastrointestinal uptake and secretion into the milk. The five fission-product radionuclides which commonly occur in milk are strontium-89, strontium-90, iodine-131, cesium-137, and barium-140. A sixth radionuclide, potassium-40, occurs naturally in 0.0118 percent (*2*) abundance of the element potassium, resulting in a specific activity for potassium-40 of 830 pCi/g total potassium.

Two stable elements which are found in milk, calcium and potassium, have been used as a means for assessing the biological behavior of

Figure 1. Milk sampling networks in the Western Hemisphere

metabolically similar radionuclides (radiostrontium and radiocesium, respectively). The contents of both calcium and potassium in milk have been measured extensively and are relatively constant. Appropriate values and their variations, expressed in terms of 2 standard deviations (2σ), for these elements are 1.16 ± 0.08 g/liter for calcium and 1.51 ± 0.21 g/liter for potassium. These figures are averages of data from the PMN for May 1963–March 1966 (*3*) and were determined for use in general radiological health calculations or discussions.

Accuracy of data from various milk networks

In order to combine data from the international, national, and State networks considered in this report, it was first necessary to determine the accuracy with which each laboratory is making its determinations and the agreement of the measurements among the laboratories. The Analytical Quality Control Service of the Office of Radiation Programs conducts periodic studies to assess the accuracy of determinations of radionuclides in milk performed by interested radiochemical laboratories. The generalized procedure for making such a study has been outlined previously (*4*).

The most recent study was conducted during May–July 1970, with 28 laboratories participating in an experiment on milk samples containing known concentrations of strontium-89, strontium-90, iodine-131, cesium-137, and barium-140 (*5*). Of the 18 laboratories producing data for the networks reporting in *Radiation Data and Reports*, 13 participated in the experiment.

The accuracy results of this experiment are shown in table 1. In general, considerable improvement is needed, especially in the accuracy measurements. These possible differences should be kept in mind when considering the integration of data from the various networks.

Development of a common reporting basis

Since the various networks collect and analyze samples differently, a complete understanding of several parameters is useful for interpreting the data. Therefore, the various milk surveillance networks that report regularly were surveyed for information on analytical methods, sampling and analysis frequencies, and estimated analytical errors associated with the data.

In general, radiostrontium is collected by an ion-exchange technique and determined by beta-particle counting in low-background detectors, and the gamma-ray emitters (potassium-40, iodine-131, cesium-137, and barium-140)

Table 1. Distribution of mean results, quality control experiment

Isotope and known concentration in milk	Number of laboratories in each category			
	Acceptable[a]	Warning level[b]	Unacceptable[c]	Total
Strontium-89: High (258 pCi/liter)	7 (44%)	1 (6%)	8 (50%)	16
Low (15 pCi/liter)	11 (69%)	3 (19%)	2 (12%)	16
Strontium-90: Intermediate (79.4 pCi/liter)	13 (57%)	4 (17%)	6 (26%)	23
Low (32.0 pCi/liter)	5 (25%)	4 (20%)	11 (55%)	20
Iodine-131: High (507 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
Low (49 pCi/liter)	16 (64%)	3 (12%)	6 (24%)	25
Cesium-137: High (259 pCi/liter)	20 (74%)	3 (11%)	4 (15%)	27
Low (53 pCi/liter)	17 (66%)	5 (19%)	4 (15%)	26
Barium-140: High (302 pCi/liter)	18 (67%)	2 (7%)	7 (26%)	27
Low (33 pCi/liter)	23 (92%)	0	2 (8%)	25

[a] Measured concentration equal to or within 2σ of the known concentration.
[b] Measured concentration outside 2σ and equal to or within 3σ of the known concentration.
[c] Measured concentration outside 3σ of the known concentration.

are determined by gamma-ray spectroscopy of whole milk. Each laboratory has its own modifications and refinements of these basic methodologies. The methods used by each of the networks have been referenced in earlier reports appearing in *Radiological Health Data and Reports.*

A previous article (*6*) summarized the criteria used by the State networks in setting up their milk sampling activities and their sample collection procedures as determined during a 1965 survey. This reference and an earlier data article for the particular network of interest may be consulted should events require a more definitive analysis of milk production and milk consumption coverage afforded by a specific network.

Many networks collect and analyze samples on a monthly basis. Some collect samples more frequently but composite the several samples for one analysis, while others carry out their analyses more often than once a month. Many networks are analyzing composite samples on a quarterly basis for certain nuclides. The frequency of collection and analysis varies not only among the networks but also at different stations within some of the networks. In addition, the frequency of collection and analysis is a function of current environmental levels. The number of samples analyzed at a particular sampling station under current conditions is reflected in the data presentation. Current levels for strontium-90 and cesium-137 are relatively stable over short periods of time, and sampling frequency is not critical. For the short-lived radionuclides, particularly iodine-131, the frequency of analysis is critical and is generally increased at the first measurement or recognition of a new influx of this radionuclide.

The data in table 2 show whether raw or pasteurized milk was collected. An analysis (*7*) of raw and pasteurized milk samples collected during January 1964 to June 1966 indicated that for relatively similar milkshed or sampling areas, the differences in concentration of radionuclides in raw and pasteurized milk are not statistically significant (*7*). Particular attention was paid to strontium-90 and cesium-137 in that analysis.

Practical reporting levels were developed by the participating networks, most often based on 2-standard-deviation counting errors or 2-standard-deviation total analytical errors from replicate analyses (*3*). The practical reporting level reflects analytical factors other than statistical radioactivity counting variations and will be used as a practical basis for reporting data.

The following practical reporting levels have been selected for use by all networks whose practical reporting levels were given as equal to or less than the given value.

Radionuclide	Practical reporting-level (pCi/liter)
Strontium-89	5
Strontium-90	2
Iodine-131	10
Cesium-137	10
Barium-140	10

Some of the networks gave practical reporting levels greater than those above. In these cases the larger value is used so that only data considered by the network as meaningful will be presented. The practical reporting levels apply to the handling of individual sample determinations. The treatment of measurements equal to or below these practical reporting levels for calculation purposes, particularly in calculating monthly averages, is discussed in the data presentation.

Analytical error or precision expressed as pCi/liter or percent in a given concentration range have also been reported by the networks (*3*). The precision errors reported for each of the radionuclides fall in the following ranges:

Radionuclide	Analytical errors of precision (2 standard deviations)
Strontium-89	1–5 pCi/liter for levels <50 pCi/liter; 5–10% for levels ≥50 pCi/liter;
Strontium-90	1–2 pCi/liter for levels <20 pCi/liter; 4–10% for levels ≥20 pCi/liter;
Iodine-131, Cesium-137, Barium-140	4–10 pCi/liter for levels <100 pCi/liter; 4–10% for levels ≥100 pCi/liter.

Table 2. Concentrations of radionuclides in milk for September 1971 and 12-month period, October 1970 through September 1971

Sampling locations		Type of sample[a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES:						
Ala:	Montgomery[c]	P	NA	7	23	11
Alaska:	Palmer[c]	P	4	5	13	14
Ariz:	Phoenix[c]	P	NA	1	0	0
Ark:	Little Rock[c]	P	14	12	21	12
Calif:	Sacramento[c]	P	NA	1	0	0
	San Francisco[c]	P	NA	4	0	0
	Del Norte	P	NA		NA	
	Fresno	P	0	2	0	2
	Humboldt	P	3	4	0	4
	Los Angeles	P	0	2	0	0
	Mendocino	P	2	6	0	5
	Sacramento	P	2	3	0	2
	San Diego	P	0	1	12	2
	Santa Clara	P	0	2	0	2
	Shasta	P	2	3	12	4
	Sonoma	P	0	3	13	4
Colo:	Denver[c]	P	NA	4	0	6
	East	R	[d]		NS	<0
	Northeast	R	[d]		NS	<1
	Northwest	R	[d]		<0	<0
	South Central	R	[d]		NS	NS
	Southeast	R	[d]		<0	<0
	Southwest	R	[d]		<0	<3
	West	R	[d]		NS	<0
Conn:	Hartford[c]	P	NA	7	0	9
	Central	P	7	7	13	15
Del:	Wilmington[c]	P	NA	9	0	6
D.C:	Washington[c]	P	NA	7	0	9
Fla:	Tampa[c]	P	5	5	52	44
	Central	R	6	6	64	40
	North	R	14	9	21	28
	Northeast	R	5	7	47	32
	Southeast	R	7	6	45	66
	Tampa Bay area	P	9	6	47	45
	West	R	13	10	27	17
Ga:	Atlanta[c]	P	NA	11	15	14
Hawaii:	Honolulu[c]	P	2	2	0	2
Idaho:	Idaho Falls[c]	P	5	5	0	6
Ill:	Chicago[c]	P	7	7	11	11
Ind:	Indianapolis[c]	P	NA	7	12	6
	Central	P	8	8	15	12
	Northeast	P	8	9	15	15
	Northwest	P	9	10	20	13
	Southeast	P	9	10	10	14
	Southwest	P	10	10	15	13
Iowa:	Des Moines[c]	P	NA	6	0	3
	Iowa City	P	6	8	13	15
	Des Moines	P	6	7	13	12
	Spencer	P	6	5	12	12
	Little Cedar	P	6	6	16	16
Kans:	Wichita[c]	P	6	7	0	2
	Coffeyville	P	9	9	14	15
	Dodge City	P	6	7	9	6
	Falls City, Nebr	R	NS		NS	
	Hays	P	6	9	8	7
	Kansas City	P	5	9	10	15
	Topeka	P	6	9	12	11
	Wichita	P	6	11	14	11
Ky:	Louisville[c]	P	NA	9	12	5
La:	New Orleans[c]	P	15	14	23	20
Maine:	Portland[c]	P	NA	9	26	22
Md:	Baltimore[c]	P	NA	8	0	6
Mass:	Boston[c]	P	9	9	19	16
Mich:	Detroit[c]	P	NA	7	11	11
	Grand Rapids[c]	P	NA	9	0	12
	Bay City	P	NS	6	NS	15
	Charlevoix	P	9	10	15 (2)	15
	Detroit	P	6	9	11	7
	Grand Rapids	P	5	7	15	9
	Lansing	P	6	7	17	15
	Marquette	P	9	10	21 (2)	24
	Monroe	P	3	5	0 (2)	4
	South Haven	P	7	7	12	9
Minn:	Minneapolis[c]	P	NA	9	0	15
	Bemidji	P	8	9	22	20
	Duluth	P	16	15	30	23
	Fergus Falls	P	8	7	18	12
	Little Falls	P	16	17	45	28
	Mankato	P	5	6	0	11
	Minneapolis	P	13	19	17	15
	Rochester	P	7	8	15	12
	Worthington	P	NS	5	NS	0

See footnotes at end of table.

Table 2. Concentrations of radionuclides in milk for September 1971 and 12-month period, October 1970 through September 1971—continued

Sampling locations		Type of sample[a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average
UNITED STATES—Continued						
Miss:	Jackson[c]	P	NA	12	16	10
Mo:	Kansas City[c]	P	NA	7	15	6
	St. Louis[c]	P	NA	6	0	6
Mont:	Helena[c]	P	NA	6	0	10
Nebr:	Omaha[c]	P	NA	6	0	4
Nev:	Las Vegas[c]	P	NA	2	0	1
N.H:	Manchester[c]	P	NA	9	21	21
N.J:	Trenton[c]	P	NA	9	0	10
N. Mex:	Albuquerque[c]	P	NA	3	0	0
N.Y:	Buffalo[c]	P	7	7	13	12
	New York City[c]	P	NA	9	0	14
	Syracuse[c]	P	NA	7	0	10
	Albany	P	0	7	<0 (4)	<0
	Buffalo	P	0	0	<0	<0
	Massena	P	6	7	22 (2)	22
	New York City	P	NS		NS	
	Syracuse	P	6	5	<0	<0
N.C:	Charlotte[c]	P	NA	11	16	12
N. Dak:	Minot[c]	P	NA	10	18	10
Ohio:	Cincinnati[c]	P	NA	7	0	2
	Cleveland[c]	P	NA	8	0	9
Okla:	Oklahoma City[c]	P	NA	6	0	8
Oreg:	Portland[c]	P	4	5	17	6
	Baker	P	5	3	<0	5
	Coos Bay	P	0	5	24	9
	Eugene	P	0	2	<0	2
	Medford	P	4	2	<0	3
	Portland composite	P	NS	6	NS	4
	Portland local	P	6	4	15	11
	Redmond	P	6	3	<0	2
	Tillamook	P	0	5	<0	13
Pa:	Philadelphia[c]	P	NA	8	0	9
	Pittsburgh[c]	P	NA	11	0	12
	Dauphin	P	NS	3	NS	13
	Erie	P	7	7	0	15
	Philadelphia	P	4	8	14	15
	Pittsburgh	P	6	11	13	17
R.I:	Providence[c]	P	NA	8	14	18
S.C:	Charleston[c]	P	9	9	13	15
S. Dak:	Rapid City[c]	P	NA	6	11	6
Tenn:	Chattanooga[c]	P	NA	9	13	10
	Memphis[c]	P	NA	7	0	8
	Chattanooga	P	7	8	17	16
	Clinton	R	8	9	0 (2)	16
	Fayetteville	R	3	9	0 (2)	13
	Kingston	P	4	7	16	18
	Knoxville	P	8	6	0 (2)	13
	Lawrenceburg	R	5	5	0 (3)	5
	Nashville	P	7	6	0	13
	Pulaski	R	8	8	0	4
Tex:	Austin[c]	P	NS	1	NS	0
	Dallas[c]	P	NA	6	0	5
	Amarillo	R	3	3	0	2
	Corpus Christi	R	NS	4	NS	0
	El Paso	R	NS	3	NS	0
	Fort Worth	R	NS	4	NS	0
	Harlingen	R	NS	2	NS	0
	Houston	R	NS	7	NS	16
	Lubbock	R	NS	3	NS	0
	Midland	R	NS	2	NS	0
	San Antonio	R	3	4	0	0
	Texarkana	R	NS		NS	
	Tyler	R	11	15	0	15
	Uvalde	R	NS		NS	
	Wichita Falls	R	NS	6	NS	4
Utah:	Salt Lake City[c]	P	3	5	0	15
Vt:	Burlington[c]	P	NA	6	14	14
Va:	Norfolk[c]	P	NA	9	0	6
Wash:	Seattle[c]	P	NA	5	14	5
	Spokane[c]	P	NA	6	0	4
	Benton County	R	0	1	0	2
	Franklin County	R	NS	4	NS	5
	Sandpoint, Idaho	R	12	13	18	22
	Skagit County	R	9	8	12	12
W. Va:	Charleston[c]	P	NA	8	0	8
Wisc:	Milwaukee[c]	P	NS	6	NS	11
Wyo:	Laramie[c]	P	NA	5	0	1
CANADA:						
Alberta:	Calgary	P	6	7	19	20
	Edmonton	P	9	7	25	24

See footnotes at end of table.

Table 2. Concentration of radionuclides in milk for September 1971 and 12-month period, October 1970 through September 1971—continued

Sampling locations		Type of sample[a]	Radionuclide concentration (pCi/liter)			
			Strontium-90		Cesium-137	
			Monthly average[b]	12-month average	Monthly average[b]	12-month average
CANADA—Continued						
British Columbia:	Vancouver	P	10	9	30	24
Manitoba:	Winnipeg	P	8	7	15	23
New Brunswick:	Fredericton	P	14	12	21	24
Newfoundland:	St. John's	P	31	17	35	31
Nova Scotia:	Halifax	P	9	11	22	24
Ontario:	Ottawa	P	14	14	35	33
	Sault Ste. Marie	P	11	12	33	26
	Thunder Bay	P	8	6	15	15
	Toronto	P	4	5	11	13
	Windsor	P	4	5	13	11
Quebec:	Montreal	P	7	7	14	18
	Quebec	P	12	10	24	30
Saskatchewan:	Regina	P	8	7	19	15
	Saskatoon	P	9	9	18	18
CENTRAL AND SOUTH AMERICA:						
Canal Zone:	Cristobal[c]	P	NA	1	0	8
Colombia:	Bogota	P	3	2	0	0
Chile:	Santiago	P	3	0	0	2
Ecuador:	Guayaquil	P	0	0	0	0
Jamaica:	Montego Bay	P	9	5	213	83
Puerto Rico:	San Juan[c]	P	NA	3	0	11
Venezuela:	Caracas	P	0	1	0	0
PMN network average[f]			7	7	7	9

[a] P, pasteurized milk.
R, raw milk.

[b] When an individual sampling result was equal to or less than the practical reporting level, a value of "0" was used for averaging. Monthly averages less than the practical reporting level reflect the fact that some but not all of the individual samples making up the average contained levels greater than the practical reporting level. When more than one analysis was made in a monthly period, the number of samples in the monthly average is given in parentheses.

[c] Pasteurized Milk Network station. All other sampling locations are part of the State or National network.

[d] Radionuclide analysis not routinely performed.

[e] The practical reporting levels for these networks differ from the general ones given in the text. Sampling results for the networks were equal to or less than the following practical reporting levels:
Iodine-131: Colorado—25 pCi/liter; Michigan—14 pCi/liter; Oregon—15 pCi/liter
Cesium-137: Colorado—25 pCi/liter; New York—20 pCi/liter; Oregon—15 pCi/liter
Strontium-90: New York—3 pCi/liter

[f] This entry gives the average radionuclides concentrations for the Pasteurized Milk Network stations denoted by footnote[c].

NA, no analysis.
NS, no sample collected.

For iodine-131, cesium-137, and barium-140, there is one exception for these precision error ranges: 25 pCi/liter at levels <100 pCi/liter for Colorado. This is reflected in the practical reporting level for the Colorado milk network.

Federal Radiation Council guidance applicable to milk surveillance

In order to place the U.S. data on radioactivity in milk presented in *Radiation Data and Reports* in perspective, a summary of the guidance provided by the Federal Radiation Council for specific environment conditions was presented in the December 1970 issue of *Radiological Health Data and Reports.*

Data reporting format

Table 2 presents the integrated results of the international, national, and State networks discussed earlier. Column 1 lists all the stations which are routinely reported to *Radiation Data and Reports.* The relationship between the PMN stations and the State stations is shown in figure 2. The first column under each of the reported radionuclides gives the monthly average for the station and the number of samples analyzed in that month in parentheses. When an individual sampling result is equal to or below the practical reporting level for the radionuclide, a value of zero is used for averaging. Monthly averages are calculated using the

above convention. Averages which are equal to or less than the practical reporting levels reflect the presence of radioactivity in some of the individual samples greater than the practical reporting level.

The second column under each of the radionuclides reported gives the 12-month average for the station as calculated from the preceding 12 monthly averages, giving each monthly average equal weight. Since the daily intake of radioactivity by exposed population groups, averaged over a year, constitutes an appropriate criterion for the case where the FRC radiation protection guides apply, the 12-month average serves as a basis for comparison.

Discussion of current data

In table 2, surveillance results are given for strontium-90, and cesium-137 for September 1971 and the 12-month period, October 1970 to September 1971. Except where noted, the monthly average represents a single sample for the sampling station. Strontium-89, iodine-131 and barium-140 data have been omitted from table 2 since levels at the great majority of the stations for September 1971 were below the respective practical reporting levels. Table 3 gives monthly averages for those stations at which strontium-89 was detected.

Strontium-90 monthly averages ranged from 0 to 16 pCi/liter in the United States for September 1971, and the highest 12-month average was 19 pCi/liter (Minneapolis, Minn., State) representing 9.5 percent of the Federal Radiation Council radiation protection guide. Cesium-137 monthly averages ranged from 0 to

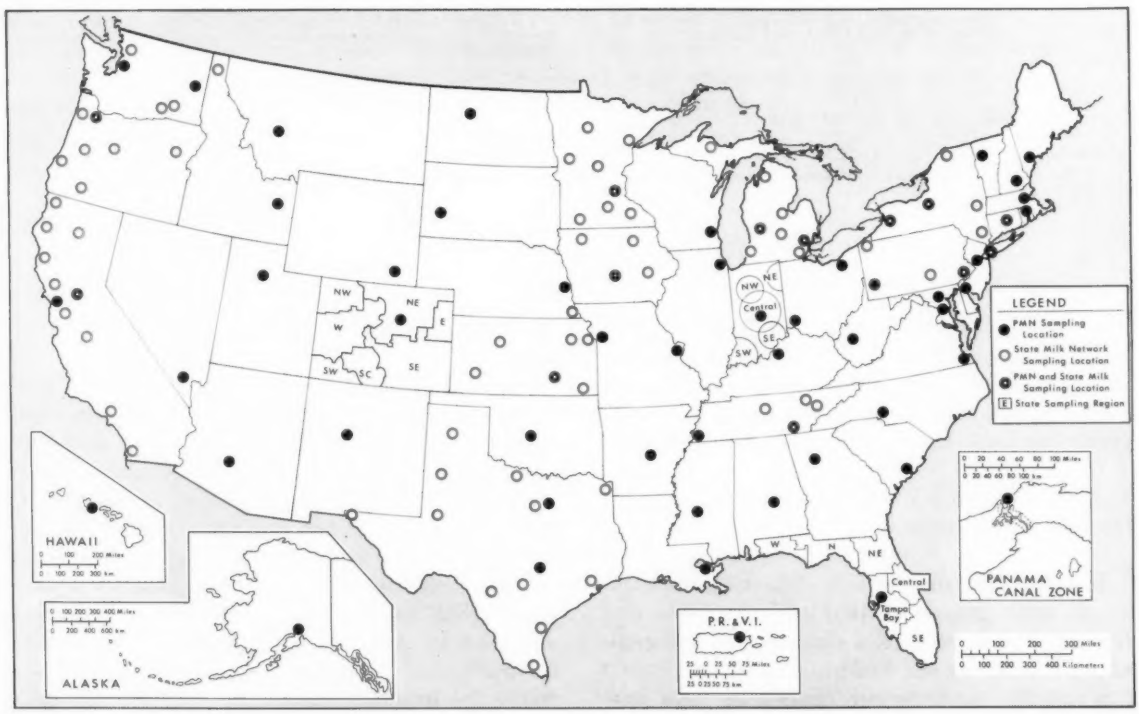

Figure 2. State and PMN milk sampling locations in the United States

64 pCi/liter in the United States for September 1971, and the highest 12-month average was 66 pCi/liter (Southeast Florida), representing 1.8 percent of the value derived from the recommendations given in the Federal Radiation Council report. Of particular interest are the consistently higher cesium-137 levels that have been observed in Florida (*8*) and Jamaica.

Table 3. Strontium-89 in milk, September 1971

Sampling location		Radionuclide concentration (pCi/liter)
Tenn:	Clinton (State)	5
	Fayetteville (State)	7
	Lawrenceburg (State)	6
Chile:	Santiago (PAHO)	17
Colombia:	Bogota (PAHO)	11
Ecuador:	Guayaquil (PAHO)	19
Venezuela:	Caracas (PAHO)	16

Acknowledgement

Appreciation is expressed to the personnel of the following agencies who provide data for their milk surveillance networks:

Bureau of Radiological Health
Division of Environmental Sanitation
California State Department of Health

Radiation Protection Division
Canadian Department of National Health and Welfare

Radiological Health Section
Division of Occupational and Radiological Health
Colorado Department of Health

Radiological Health Services
Division of Medical Services
Connecticut State Department of Health

Radiological and Occupational Health Section
Department of Health and Rehabilitative Services
State of Florida

Bureau of Environmental Sanitation
Division of Sanitary Engineering
Indiana State Board of Health

Division of Radiological Health
Environmental Engineering Services
Iowa State Department of Health

Radiation Control Section
Environmental Health Division
Kansas State Department of Health

Radiological Health Services
Division of Occupational Health
Michigan Department of Health

Radiation Control Section
Division of Environmental Health
State of Minnesota Department of Health

Bureau of Radiological Pollution Control
New York State Department of Environmental Conservation

Environmental Radiation Surveillance Program
Division of Sanitation and Engineering
Oregon State Board of Health

Radiological Health Section
Bureau of Environmental Health
Pennsylvania Department of Public Health

Radiological Health Services
Division of Preventable Diseases
Tennessee Department of Public Health

Division of Occupational Health
Environmental Health Services
Texas State Department of Health

Radiation Control Section
Division of Health
Washington Department of Social and Health Services

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(1) CAMPBELL, J. E., G. K. MURTHY, A. S. GOLDIN, H. B. ROBINSON, C. P. STRAUB, F. J. WEBER and K. H. LEWIS. The occurrence of strontium-90, iodine-131, and other radionuclides in milk, May 1957 through April 1958. Amer J Pub Health 49:225 (February 1969).
(2) U.S. ATOMIC ENERGY COMMISSION, DIVISION OF ISOTOPES DEVELOPMENT. Chart of the Nuclides, Tenth Edition revised to December 1968. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
(3) NATIONAL CENTER FOR RADIOLOGICAL HEALTH. Section I. Milk Surveillance. Radiol Health Data Rep 9:730–746 (December 1968).
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(6) NEILL, R. H. and D. R. SNAVELY. State Health Department sampling criteria for surveillance of radioactivity in milk. Radio Health Data Rep 8:621–627 (November 1967).
(7) ROBINSON, P. B. A comparison of results between the Public Health Service Raw Milk and Pasteurized Milk Networks for January 1964 through June 1966. Radiol Health Data Rep 9:475–488 (September 1968).
(8) PORTER, C. R., C. R. PHILLIPS, M. W. CARTER, and B. KAHN. The cause of relatively high cesium-137 concentrations in Tampa, Florida, milk Radioecological Concentration Processes, Proceedings of an International Symposium held in Stockholm, April 25–29, 1966. Pergamon Press, New York, N.Y. (1966) pp. 95–101.

Food and Diet Surveillance

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuing basis. These estimates, along with the guidance developed by the Federal Radiation Council, provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in operation and reported routinely include those listed below. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs reported in *Radiological Health Data and Reports* are as follows:

Program	Period reported	Issue
California Diet Study	July-December 1970	November 1971
Carbon-14 in Total Diet and Milk	January-June 1971	December 1971
Connecticut Standard Diet	January-December 1970	December 1971
Institutional Diet Samples	April-June 1971	November 1971

SECTION II. WATER

The Environmental Protection Agency and other Federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values with the Public Health Service Drinking Water Standards (*1*). These standards, based on consideration of Federal Radiation Council (FRC) recommendations (*2–4*), set the limits for approval of a drinking water supply containing radium-226 and strontium-90 at 3 pCi/liter and 10 pCi/liter, respectively. Higher concentrations may be acceptable if the total intake of radioactivity from all sources remains within the guides recommended by FRC for control action. In the known absence[1] of strontium-90 and alpha-particle emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when additional analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the limits indicated by the Radiation Protection Guides. Surveillance data from a number of Federal and State programs are published periodically to show current and long-range trends. Water sampling activities reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 3 pCi/liter and 10 pCi/liter for unidentified alpha-particle emitters and strontium-90, respectively.

Water sampling program	Period reported	Issue
California	January-December 1969	October 1971
Gross Radioactivity in Surface Waters of the United States	March 1971	November 1971
Interstate Carrier Drinking Water	1970	July 1971
Kansas	January-December 1970	December 1971
Minnesota	January-June 1970	November 1971
North Carolina	January-December 1967	May 1969
New York	July 1969-June 1970	September 1971
Tritium in Community Water Supplies	1969	December 1970
Tritium Surveillance System	April-June 1971	November 1971
Washington	July 1968-June 1969	February 1971

REFERENCES

(*1*) U.S. PUBLIC HEALTH SERVICE. Drinking water standards, revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

(*2*) FEDERAL RADIATION COUNCIL. Radiation Protection Guidance for Federal Agencies. Memorandum for the President, September 1961. Reprint from the Federal Register of September 26, 1961.

(*3*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 1. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (May 1960).

(*4*) FEDERAL RADIATION COUNCIL. Background material for the development of Radiation Protection Standards, Report No. 2. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (September 1961).

Gross Radioactivity in Surface Waters of the United States, April and May 1971

Office of Water Programs
Environmental Protection Agency

The monitoring of gross radioactivity in surface waters of the United States was initiated in 1957 as part of the Water Pollution Surveillance System (formerly National Water Quality Network) of the U.S. Public Health Service. Currently, the program is operated by the Environmental Protection Agency, Office of Water Programs. Regional offices of the Environmental Protection Agency are responsible for the collection of samples and the entering of the resulting data into the analytical storage and retrieval system. Radioactivity analyses are performed in the centralized radioactivity laboratories of the Office of Water Programs (Cincinnati, Ohio).

The regular reporting of gross radioactivity data in *Radiological Health Data and Reports* was terminated with the publication of data for October 1968 (April 1969 issue). With the publication of data for January 1971, it is intended to reinitiate this activity as a monthly report series. The unpublished data for the time interval of November 1968 through December 1970 will be the subject of a future summary article.

Table 1 presents the gross alpha and beta results for samples collected from 14 rivers during April 1971. Table 2 presents the sample results collected from 13 rivers during May 1971. The analytical procedure used for determining gross alpha and gross beta radioactivity

Table 1. Gross alpha and beta radioactivity in U.S. surface waters, April 1971

River and station	Number of grab samples[a]	Gross alpha radioactivity (pCi/liter)				Gross beta radioactivity (pCi/liter)			
		Suspended solids		Dissolved solids		Suspended solids		Dissolved solids	
Cheyenne River:									
Edgemont, S. Dak.	1	13		11		47		27	
Clinch River:									
Kingston, Tenn.	4	<.8	(<.2–1)	<.2	(<.2–<.2)	4.7	(<1–9)	4.7	(3–8)
Great Miami River:									
Eldian Mills, Ohio	1	<.2		2		11		10	
Sellar Road, Ohio	1	<.2		1		5		8	
Fairfield, Ohio	1	<.2		1		1		12	
American Materials Bridge, Ohio	1	<.2		1		2		11	
Lost Bridge, Ohio	1	<.2		2		3		16	
Kentucky River:									
Lock & Dam No. 1, Ky.	1	<.2		<.2		7		4	
Licking River:									
Covington, Ky.	1	<.2		<.2		1		9	
Little Miami River:									
Cincinnati, Ohio	1	<.2		1		2		5	
Mississippi River:									
Burlington, Iowa	1	6		1		21		8	
Missouri River:									
Bismark, N. Dak.	1	<.2		3		2		7	
Ohio River:									
Ironton, Ohio	1	<.2		<.2		7		4	
Greenup Dam, Ky.	1	<.2		<.2		<1		7	
Portsmouth, Ohio	1	1		<.2		3		3	
Maysville, Ky.	1	1		<.2		2		7	
Cincinnati, Ohio	4	<.4	(<.2–1)	<.6	(<.2–1)	2	(1–4)	4.7	(2–6)
Anderson Ferry, Ohio	1	<.2		<.2		3		8	
Miami Fort, Ohio	1	<.2		1		3		3	
Markland Dam, Ky.	1	1		<.2		6		4	
Madison, Ind.	1	<.2		<.2		7		6	
Meldahl Dam, Ohio	1	<.2		<.2		2		9	
Roanoke River:									
John Kerr Dam, Va.	4	<.4	(<.2–1)	<.2	(<.2–<.2)	3.5	(2–7)	4.7	(4–6)
Susquehanna River:									
Holtwood, Pa.	1	1		<.2		4		2	
Tennessee River:									
Bridgeport, Ala.	1	<.2		<.2		1		7	
White Water River:									
State Line (Ohio-Ind)	1	<.2		1		6		10	
Yellowstone River:									
Sidney, Mont.	1	<.2		1		6		10	

[a] Where more than one sample is analyzed during the month, the minimum and maximum values are in parentheses.

Table 2. Gross radioactivity in U.S. surface waters, May 1971

River and station	Number of grab samples	Gross alpha radioactivity (pCi/liter)		Gross beta radioactivity (pCi/liter)	
		Suspended solids	Dissolved solids	Suspended solids	Dissolved solids
Cheyenne River:					
Edgemont, S. Dak.	1	36	11	95	62
Clinch River:					
Kingston, Tenn.	[a]5	<.2 (<.2- <.2)	<.2 (<.2- <.2)	<1 (<1-1)	5.8 (3-10)
Great Miami River:					
Eldean Mills, Ohio	1	<.2	3	<.2	9
Sellar Road, Ohio	1	<.2	2	1	2
Fairfield, Ohio	1	<.2	1	3	5
American Materials Bridge, Ohio	1	<.2	<.2	6	13
Lost Bridge, Ohio	1	1	<.2	3	22
Kentucky River:					
Lock and Dam No. 1, Ky.	1	<.2	<.2	8	3
Licking River:					
Covington, Ky.	1	7	<.2	3	2
Little Miami River:					
Cincinnati, Ohio	1	1	1	12	11
Mississippi River:					
Dubuque, Iowa	1	1	1	<1	7
Burlington, Iowa	1	1	1	<1	3
Ohio River:					
Ironton, Ohio	1	<.2	<.2	2	4
Greenup Dam, Ky.	1	<.2	<.2	2	6
Portsmouth Ohio	1	1	<.2	3	2
Maysville, Ky.	1	1	<.2	6	5
Cincinnati, Ohio	[a]5	<1.2 (<.2-2)	<.4 (<.2-1)	<4.7 (<1-11)	5.7 (2-7)
Miami Fort, Ohio	1	5	<.2	13	1
Anderson Ferry, Ohio	1	1	<.2	9	1
Markland Dam, Ky.	1	1	<.2	4	6
Madison, Ind.	1	1	<.2	7	5
Meldahl Dam, Ohio	1	1	<.2	7	5
Rainy River:	1				
International Falls, Minn.	1	<.2	1	2	6
Roanoke River:					
John Kerr Dam	[a]3	<.2 (<.2-<.2)	<.2 (<.2-<.2)	<.1 (<1-<1)	2 (<1-4)
St. Lawrence River:					
Massena, N.Y.	[a]3	<.2 (<.2-<.2)	<.2 (<.2-<.2)	1.3 (1-2)	4.7 (3-6)
Susquehanna River:					
Conowingo Dam, Md.	1	<.2	<.2	2	2
Whitewater River:					
State line (Ohio-Ind.)	1	1	<.2	4	5

[a] Where more than one sample is analyzed, the minimum and maximum values at in parentheses.

are described in the 13th Edition of *Standard Methods for the Examination of Water and Wastewater* (*1*). Results are reported for the date of counting and are not corrected to the date of collection. The sensitivity in counting is that defined by the National Bureau of Standards, Handbook 86 (*2*) and is calculated to be < 0.2 pCi/liter for gross alpha radioactivity and < 1 pCi/liter for gross beta radioactivity measurements.

REFERENCES

(*1*) AMERICAN PUBLIC HEALTH ASSOCIATION; AMERICAN WATER WORKS ASSOCIATION AND WATER POLLUTION CONTROL FEDERATION. Standard methods for the examination of water and wastewater, 13th Edition, (1971) New York, N.Y.

(*2*) U.S. DEPARTMENT OF COMMERCE. Radioactivity, Recommendations of the International Commission on Radiological Units and Measurements (1962), NBS Handbook 86 (November 29, 1963).

Radioactivity in Florida Waters, 1969

Radiological and Occupational Health Section
Florida State Division of Health

The Florida State Division of Health samples raw surface, ground, and treated water in 13 hydrological subbasins as shown in figure 1. Samples collected on a variable frequency and analyzed for gross alpha and beta radioactivity during 1969 are presented in table 1.

In addition to sampling being done by the Florida State Division of Health, the Bioenvironmental Engineering Research Laboratory, University of Florida, samples surface, ground, and municipal water in Alachua County for gross beta radioactivity. Samples are taken monthly from each sampling point with the exception of the City of Gainesville where raw water is sampled daily. These data for 1969 are summarized in table 2. Gross beta radioactivity above the minimum reported concentration was detected in 17 water samples taken in Alachua County. The 17 samples averaged 13 pCi/liter of gross beta radioactivity.

During 1969, only 17 samples out of a total of 83 collected from 63 sampling sites showed gross beta radioactivity greater than the minimum reported concentration. The 17 surface,

[1] Data taken from "Report of Florida Radiological Surveillance Programs, 1969" Bureau of Preventable Diseases, Radiological and Occupational Health Section, Jacksonville, Fla.

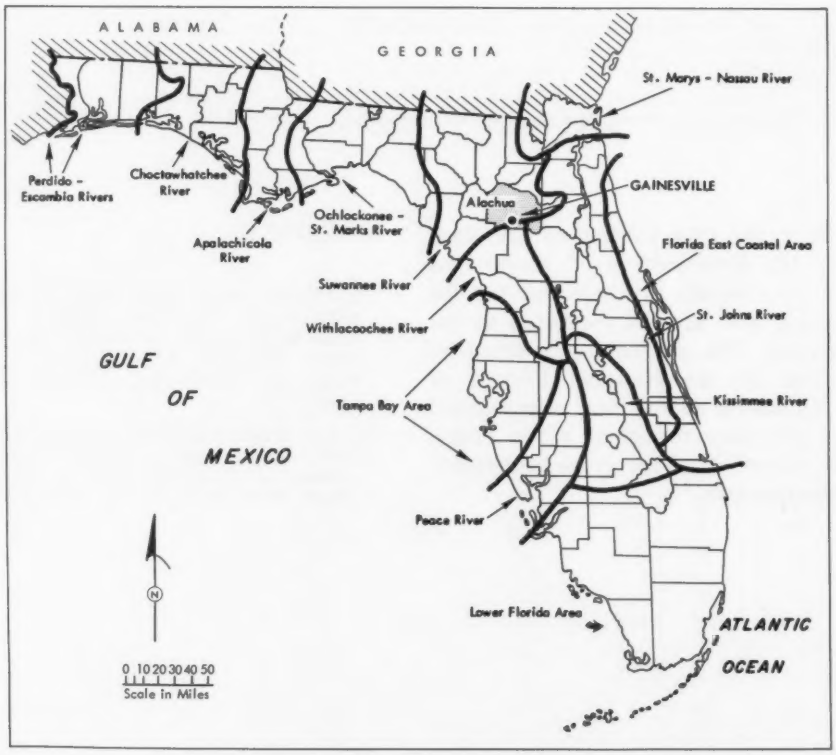

Figure 1. Hydrological surface subbasins in Florida

Table 1. Gross alpha and beta radioactivity in Florida water, 1969

Location	Number of samples	Alpha (pCi/liter)	Beta (pCi/liter)
St. John's River:			
Raw	14	<7	<10
	1	<7	11
	1	<7	12
	1	<7	53
Treated	6	<7	<10
Sewage treatment plants	[a]2	<7	<10
St. Mary's, Nassau, and Amelia Rivers:			
Raw	1	<7	62
	1	<7	<10
Lower Florida area:			
Raw	10	<7	<10
Treated	14	<7	<10
	[a]1	<7	19
	[a]1	<7	12
Sewage treatment plant	1	<7	12
	1	<7	21
	[a]1	<7	13
	[a]1	<7	16
	[a]1	<7	11
	[a]1	<7	<10
Florida East Coastal area:			
Raw	2	<7	<10
Treated	3	<7	<10
Kissimmee River Basin:			
Treated	1	<7	12
Sewage treatment plant	[a]1	<7	<10
	[a]1	<7	14
Peace River:			
Treated	3	<7	<10
Tampa Bay area:			
Raw	1	<7	<10
Treated	6	<7	<10
Sewage treatment plants	[a]3	<7	12
	[a]1	<7	15
Withlacoochee and Waccasassa Rivers:			
Treated	2	<7	<10

[a] Composite sample.

ground, and municipal water samples averaged 19 pCi/liter. The average gross beta radioactivity in water samples is well below the limitations imposed by the standard for gross beta radioactivity in drinking water (1,000 pCi/liter) (*1*).

REFERENCE

(*1*) PUBLIC HEALTH SERVICE. Public Health Service Drinking Water Standards, Revised 1962, PHS Publication No. 956. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (March 1963).

Table 2. Gross beta radioactivity in Florida water, 1969

Location	Radioactivity concentration (pCi/liter)												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Summary
Alachua County: (18 sampling locations)													
Maximum	12.6	7.5	15.6	7.2	9.6	6.8	21.4	9.7	14.3	8.9	10.4	13.1	21.4
Average	2.9	3.2	7.9	3.7	4.5	3.2	8.6	5.2	5.2	4.9	4.8	5.0	4.9
City of Gainesville:													
Maximum	10.9	10.1	10.1	6.4	7.2	8.6	7.5	10.0	10.4	6.7	15.6	7.2	15.6
Average	4.5	4.0	3.6	2.9	3.2	3.8	3.1	3.7	3.5	2.9	4.0	2.8	3.5

SECTION III. AIR AND DEPOSITION

Radioactivity in Airborne Particulates and Precipitation

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product radioactivity. To date, this surveillance has been confined chiefly to gross beta-radioanalysis. Although such data are insufficient to assess total human radiation exposure from fallout, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the Environmental Protection Agency, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

In addition to those programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports*:

Network	Period	Issue
Plutonium in Airborne Particulates	January-March 1971	November 1971
Mexican Air Monitoring Program	August-December 1970 and January 1971	October 1971

1. Radiation Alert Network September 1971

Environmental Protection Agency

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Alert Network (RAN) which regularly gathers samples at 70 locations distributed throughout the country (figure 1). Most of these stations are operated by State health department personnel.

The station operators perform "field estimates" on the airborne particulate samples at 5 hours after collection, when most of the radon daughter products have decayed, and at 29 hours after collection, when most of the thoron daughter products have decayed. They also perform field estimates on dried precipitation samples and report all results to appropriate Environmental Protection Agency officials by mail or telephone depending on levels found. A compilation of the daily field estimates is available upon request from the Air Quality Information Systems Branch, Division of Atmospheric Surveillance, EPA, Research Triangle Park, North Carolina 27711. A detailed description of the sampling and analytical procedures was presented in the March 1968 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air particulates and deposition by precipitation, as measured by the field estimate technique, during September 1971.

All field estimates reported were within normal limits for the reporting station.

Figure 1. Radiation Alert Network sampling stations

Table 1. Gross beta radioactivity in surface air and precipitation, September 1971

Station location		Number of samples	Gross beta radioactivity (5-hour field estimate) (pCi/m³)			Number of samples	Total depth (mm)	Precipitation		
								Field estimation of deposition		
			Maximum	Minimum	Average[a]			Number of samples	Depth (mm)	Total deposition (nCi/m²)
Ala:	Montgomery	20	4	0	1	2	112	2	112	108
Alaska:	Anchorage	2	0	0	0	0				
	Attu Island	29	0	0	0	0				
	Fairbanks	20	1	0	0	10	54	10	54	33
	Juneau	0				0				
	Kodiak	0				0				
	Nome	0				0				
	Point Barrow	0				0				
Ariz:	Phoenix	11	4	1	2	0				
Ark:	Little Rock	11	2	0	1	0				
Calif:	Berkeley	18	1	0	0	1	7	1	7	0
	Los Angeles	16	3	0	1	0				
C.Z:	Ancon	17	0	0	0	0				
Colo:	Denver	21	6	0	2	7	68			
Conn:	Hartford	21	1	0	1	3	38	3	38	0
Del:	Dover	21	1	0	0	0				
D.C:	Washington	25	1	0	0	0				
Fla:	Jacksonville	20	1	0	0	5	49			
	Miami	17	0	0	0	11	175	10	149	0
Ga:	Atlanta	21	2	1	2	0				
Guam:	Agana	0				0				
Hawaii:	Honolulu	20	1	0	0	6	76			
Idaho:	Boise	21	3	0	2	3	14	3	14	0
Ill:	Springfield	1	2	2	2	0				
Ind:	Indianapolis	21	2	0	1	0				
Iowa:	Iowa City	20	5	0	1	4	97	4	97	28
Kans:	Topeka	21	6	0	2	3	25	3	25	0
Ky:	Frankfort	0				0				
La:	New Orleans	19	1	0	0	11	333			
Maine:	Augusta	18	2	0	1	5	86	4	72	0
Md:	Baltimore	17	2	0	1	4	40	4	40	0
Mass:	Lawrence	18	2	0	1	4	32	4	32	0
	Winchester	19	3	0	1	4	43	4	43	0
Mich:	Lansing	19	1	0	1	7	116	7	116	12
Minn:	Minneapolis	17	3	0	1	5	73	5	73	12
Miss:	Jackson	17	2	0	0	3	105			
Mo:	Jefferson City	20	5	0	2	5	58	5	58	0
Mont:	Helena	19	3	0	1	5	33	5	33	0
Nebr:	Lincoln	19	11	1	4	1	4	1	4	1
Nev:	Las Vegas	20	3	1	1	0				
N.H:	Concord	0				0				
N.J:	Trenton	21	1	0	0	6	50	6	50	2
N. Mex:	Santa Fe	11	2	1	1	1	23	1	23	0
N.Y:	Albany	13	1	0	0	0				
	Buffalo	20	1	0	1	0				
	New York City	0				0				
N.C:	Gastonia	6	12	3	7	0				
N. Dak:	Bismarck	19	4	0	2	5	56	5	56	10
Ohio:	Cincinnati	0				0				
	Columbus	2	1	1	1	0				
	Painesville	20	3	0	1	7	123	7	123	50
Okla:	Oklahoma City	0				0				
	Ponca City	21	4	0	1	5	158	4	147	0
Oreg:	Portland	21	1	0	0	8	67	8	67	0
Pa:	Harrisburg	12	1	0	1	0				
P.R:	San Juan	0				0				
R.I:	Providence	20	2	0	1	4	31	4	31	0
S.C:	Columbia	15	4	0	1	4	83	4	83	0
S. Dak:	Pierre	19	5	1	2	0				
Tenn:	Nashville	4	2	0	1	1	31	1	31	0
Tex:	Austin	0				0				
	El Paso	21	5	0	2	0				
Utah:	Salt Lake City	25	4	1	1	1	4	1	4	2
Vt:	Barre	21	3	0	1	6	35	6	35	4
Va:	Richmond	18	1	0	0	2	60	2	60	0
Wash:	Seattle	8	0	0	0	4	58			
	Spokane	8	1	0	0	0				
W. Va:	Charleston	21	2	0	1	9	192	9	192	17
Wisc:	Madison	20	3	0	1	4	37	4	37	4
Wyo:	Cheyenne	19	4	0	2	3	35	3	35	13
Network summary		1,001	12	0	1	179	84	4	61	9

[a] The monthly average is calculated by weighting the field estimates of individual air samples with length of sampling period.
[b] This station is part of the tritium surveillance system. No gross beta measurements are done.

2. Canadian Air and Precipitation Monitoring Program,[1] September 1971

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 2), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*1–5*).

A summary of the sampling procedures and methods of analysis was presented in the May 1969 issue of *Radiological Health Data and Reports*.

[1] Prepared from information and data obtained from the Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for September 1971 are presented in table 2.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, September 1971

Station	Number of samples	Air surveillance gross beta radioactivity (pCi/m²)			Precipitation measurements	
		Maximum	Minimum	Average	Average concentration (pCi/liter)	Total deposition (nCi/m²)
Calgary	30	0.1	0.1	0.1	37	1.5
Coral Harbour	4	.1	.0	.1	66	1.2
Edmonton	4	.1	.1	.1	16	.8
Ft. Churchill	4	.1	.0	.1	49	4.3
Fredericton	4	.1	.1	.1	27	2.0
Goose Bay	4	.0	.0	.0	40	3.0
Halifax	4	.1	.1	.1	29	1.5
Inuvik	4	.0	.0	.0	46	1.1
Montreal	4	.1	.1	.1	30	2.3
Moosonee	4	.1	.1	.1	14	2.3
Ottawa	4	.1	.1	.1	15	.8
Quebec	1	.1	.1	.1	30	4.0
Regina	4	.1	.1	.1	110	1.1
Resolute	4	.1	.0	.0	21	.3
St. John's, Nfld.	4	.1	.0	.1	26	2.3
Saskatoon	4	.1	.1	.1	178	1.0
Sault Ste. Marie	4	.1	.1	.1	43	4.5
Thunder Bay	3	.1	.1	.1	44	4.7
Toronto	4	.1	.1	.1	53	2.0
Vancouver	4	.1	.0	.0	29	2.6
Whitehorse	4	.1	.0	.1	29	.6
Windsor	4	.1	.1	.1	8	.6
Winnipeg	4	.1	.1	.1	98	4.9
Yellowknife	4	.1	.0	.1	58	1.5
Network summary	118	0.1	0.0	0.1	46	2.1

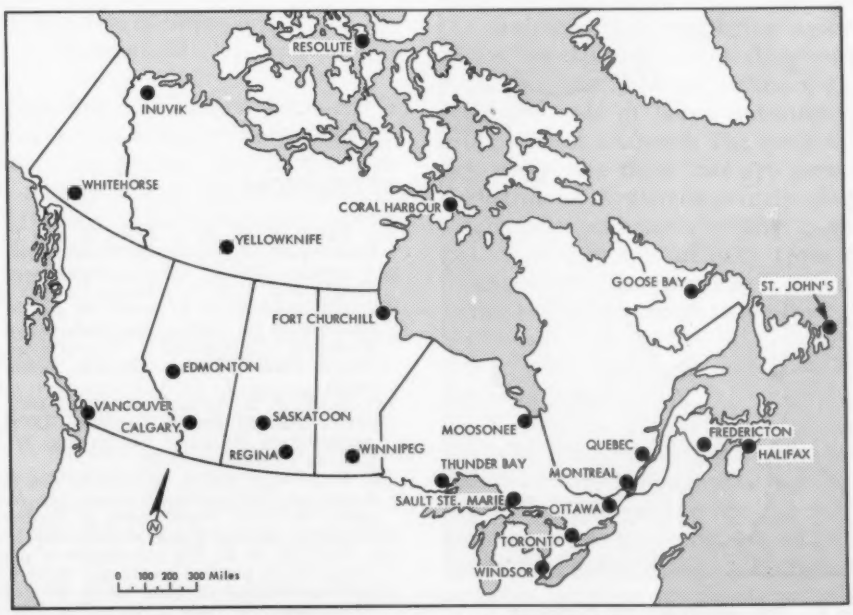

Figure 2. Canadian air and precipitation sampling stations

3. Pan American Air Sampling Program September 1971

Pan American Health Organization and Environmental Protection Agency

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the Environmental Protection Agency (EPA) to assist PAHO-member countries in developing radiological health programs.

The air sampling station locations are shown in figure 3. Analytical techniques were described in the March 1968 issue of *Radiological Health Data and Reports*. The September 1971 air monitoring results from the participating countries are given in table 3.

Figure 3. Pan American Air Sampling Program stations

Table 3. Summary of gross beta radioactivity in Pan American surface air, September, 1971

Station location		Number of samples	Gross beta radioactivity (pCi/m³)		
			Maximum	Minimum	Average[a]
Argentina:	Buenos Aires	0			
Bolivia:	La Paz	11	3.47	0.87	1.90
Chile:	Santiago	30	1.05	.04	.43
Colombia:	Bogota	22	.49	.06	.18
Ecuador:	Cuenca	19	1.01	.02	.48
	Guayaquil	21	2.11	.15	.83
	Quito	14	.30	.02	.15
Guyana:	Georgetown	17	.51	.03	.20
Jamaica:	Kingston	0			
Peru:	Lima	25	1.16	.24	.71
Venezuela:	Caracas	20	.34	.02	.13
West Indies:	Trinidad	21	.63	.02	.16
Pan American summary		200	3.47	0.02	0.47

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values less than 0.005 pCi/m³ are reported and used in averaging as 0.00 pCi/m³.

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(*1*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report of 1959 on the Radioactive Fallout Study Program, CNHW–RP–3. Department of National Health and Welfare, Ottawa, Canada (May 1960).

(*2*) BIRD, P. M., A. H. BOOTH, and P. G. MAR. Annual report for 1960 on the Radioactive Fallout Study Program, CNHW–RP–4. Department of National Health and Welfare, Ottawa, Canada (December 1961).

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(*4*) BEALE, J. and J. GORDON. The operation of the Radiation Protection Division Air Monitoring Program, RPD–11. Department of National Health and Welfare, Ottawa, Canada (July 1962).

(*5*) BOOTH, A. H. The calculation of permissible levels of fallout in air and water and their use in assessing the significance of 1961 levels in Canada, RPD–21. Department of National Health and Welfare, Ottawa, Canada (August 1962).

SECTION IV. OTHER DATA

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included here are such data as those obtained from human bone sampling, Alaskan surveillance, and environmental monitoring around nuclear facilities.

Environmental Levels of Radioactivity at Atomic Energy Commission Installations

The U.S. Atomic Energy Commission (AEC) receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the "AEC Manual." [1]

Summary of the environmental radioactivity data follow for the Argonne National Laboratory.

[1] Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" contains essentially the standards published in Chapter 0524 of the AEC Manual.

1. Argonne National Laboratory July–December 1970 [2]

University of Chicago
Lemont, Ill.

Argonne National Laboratory conducts a continuous program to measure the radioactivity on the laboratory grounds and in the area near the laboratory. The primary purpose of this phase of the laboratory's radiation protection program is to determine the magnitude, origin, and identity of any radioactivity not naturally present in the environment. Of special interest is the detection of any radioactive materials released to the environment by Argonne. If activity released by Argonne begins to approach significant levels, immediate steps will be taken to eliminate or reduce the release.

The radioactivity of the environment is determined by measuring the concentrations of radionuclides in naturally-occurring materials collected on the Argonne site and from locations up to 100 miles from the site. Since radioactivity is usually spread by air and water, the environmental monitoring program at Argonne has concentrated on these media. Plants, milk, soil, precipitation, animals, and material from the beds of lakes and streams are also collected and analyzed. The results included in this report are those that are pertinent to the evaluation of Argonne's contribution to the environmental radioactivity and to the differentiation of Argonne activity from fallout and other sources. The sampling locations discussed in this report are shown in figures 1 and 2.

[2] Summarized from "Environmental Radioactivity at Argonne National Laboratory, July-December 1970," University of Chicago, Lemont, Ill.

Air monitoring

The radioactivity of particulate matter in air was determined by drawing air through filter paper at a known rate and measuring the radioactivity of the particles collected by the paper. The samples were collected continuously at seven locations on the Argonne site and at six locations off the site. At one location on the

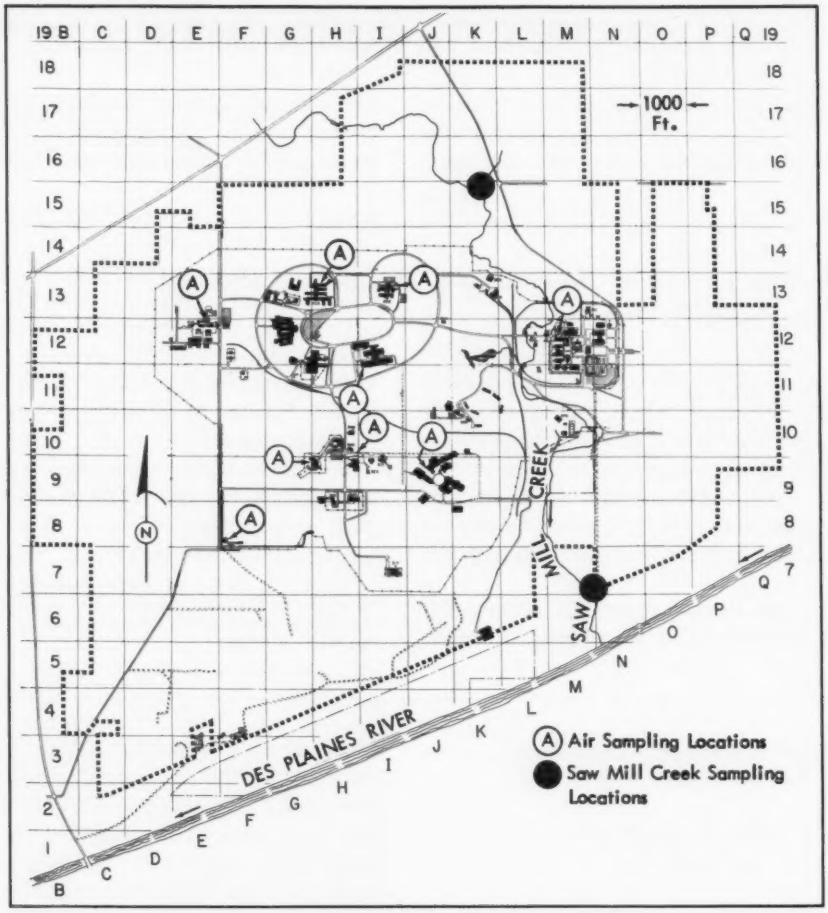

Figure 1. Onsite sampling locations at Argonne National Laboratory

Table 1. Alpha and beta radioactivity in air-filter samples[a] Argonne National Laboratory, July-December 1970

Period	Location	Number of samples	Alpha radioactivity (fCi/m³)			Beta radioactivity (pCi/m³)		
			Average	Minimum	Maximum	Average	Miminum	Maximum
July	Onsite	26	3.1	1.4	6.0	0.48	0.19	0.72
	Offsite	23	3.9	1.6	7.8	.55	.33	.93
August	Onsite	27	3.1	2.0	6.2	.38	.18	.78
	Offsite	22	4.4	2.2	10.6	.41	.22	.78
September	Onsite	22	2.1	.91	5.4	.13	.034	.27
	Offsite	20	2.7	.72	6.6	.15	.062	.26
October	Onsite	25	2.5	1.2	4.3	.14	.034	.22
	Offsite	25	2.9	.81	4.6	.14	.092	.23
November	Onsite	27	2.3	1.2	4.3	.13	.066	.25
	Offsite	24	2.4	.63	4.9	.14	.082	.31
December	Onsite	25	2.9	1.6	4.2	.12	.070	.21
	Offsite	25	3.5	1.9	6.7	.11	.050	.23
Annual summary	Onsite	289	3.0	0.91	11.7	0.26	0.03	1.09
	Offsite	258	3.9	0.63	12.7	0.28	0.03	1.16

[a] These results were obtained by measuring the samples four days after they were collected in order to avoid counting the natural radioactivity due to radon and thoron decay products.

Table 2. Gamma-ray radioactivity in air-filter samples Argonne National Laboratory, July-December 1970

Radionuclide	Location	Concentration[a] (pCi/m³)						
		July	Aug	Sept	Oct	Nov	Dec	Summary
Barium-lanthanum-140	Onsite	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	(a)
	Offsite	< .001	< .001	< .001	< .001	.003	< .001	(a)
Beryllium-7	Onsite	.092	.089	.057	.085	.072	.060	0.08
	Offsite	.099	.110	.066	.084	.071	.056	.09
Cerium-141	Onsite	.003	.002	< .001	.001	.003	.001	(a)
	Offsite	.004	.002	< .001	.001	.003	.001	(a)
Cerium-144	Onsite	.110	.087	.030	.028	.018	.013	.05
	Offsite	.110	.097	.031	.029	.018	.012	.05
Cesium-137	Onsite	.007	.007	.003	.003	.002	.002	(a)
	Offsite	.009	.008	.003	.002	.002	.001	(a)
Iodine-131	Onsite	< .01	< .01	< .01	.01	.01	.07	.01
	Offsite	< .01	< .01	< .01	.01	.01	.12	.02
Ruthenium-103	Onsite	.010	.005	.002	.002	.005	.004	.01
	Offsite	.011	.006	.002	.002	.005	.005	.01
Ruthenium-rhodium-106	Onsite	.074	.070	.025	.023	.018	.017	.04
	Offsite	.078	.071	.031	.028	.020	.017	.04
Zirconium-niobium-95	Onsite	.130	.086	.024	.021	.016	.011	.06
	Offsite	.140	.094	.025	.020	.016	.010	.07

[a] Because of a change in counting equipment in the second half of the year which improved sensivitity by a factor of ten, no meaningful average could be calculated.

site the filter paper was changed daily; at all other locations the filter papers were changed at weekly intervals. The daily samples record short-term changes in radioactivity, while the weekly samples are used to compare onsite and offsite activities. High radioactivity on the site is indicative of radioactivity released by Argonne if the difference between this radioactivity and normal background is greater than the 10 to 20 percent error in sampling and counting. The alpha and beta radioactivity in air-filter samples are summarized in table 1; the average concentration of gamma-ray emitters as determined by gamma ray spectrometry are summarized in table 2.

During the second half of the year, the gamma-ray spectra were obtained with a large volume, high resolution, shielded, lithium-drifted germanium detector. This counting system improved the sensitivity by a factor of 10 over the sodium iodide detector previously used. Because of this difference in sensitivity, no meaningful annual averages could be calculated for some nuclides, as indicated in table 2.

The activities were very similar on and off the site, indicating that Argonne did not add significantly to the air-borne particulate activity of the environment during the year, and that the activities originated in a widespread source, such as fallout from nuclear test detonations or naturally-occurring materials, and not in a localized source, such as the laboratory.

The alpha radioactivity concentrations were normal and in the range found in previous years. As in the past, much of the beta and gamma radioactivity was due to fission and neutron activation products from nuclear detonations, although about one-third of the gamma radioactivity and a smaller fraction of the beta radioactivity was due to beryllium-7, produced in the stratosphere by cosmic-ray interactions. The concentrations of total beta radioactivity and of all the gamma-ray emitters for which positive results were obtained, increased steadily from January to June, then decreased during the remainder of the year. This variation can be attributed to the increased stratospheric fallout usually observed in the spring.

Since the fission product concentrations varied in approximately the same manner as beryllium-7, except that they decreased at a greater rate during the latter part of the year through radioactive decay, the bulk of the fission products was also derived from the stratosphere. The presence of the fission products can be correlated with announced nuclear tests. The average beta radioactivity for the year, 0.27 pCi/m³, was about 15 percent higher than in 1969. The bulk of this increase occurred during the second quarter and was principally due to the increased concentrations of intermediate half-life fission products, notably zirconium-niobium-95 and cerium-144. Because iodine-131 and barium-140 were not detected before the appearance of the zirconium-niobium-95 and

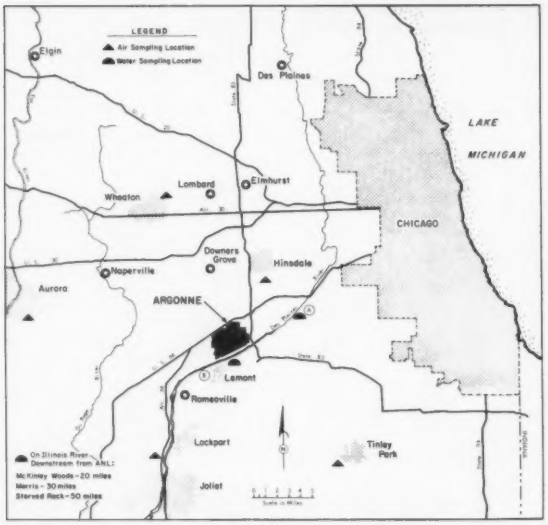

Figure 2. Location of Argonne National Laboratory (including some offsite sampling locations)

cerium-144, the implication is that the latter fission products came from the stratosphere. The detection of short-lived fission products, such as iodine-131, barium-140, and ruthenium-103 at all sampling locations during the last quarter of the year indicates the presence of fission products of recent origin.

Additional measurements made on the air-filter samples showed that small amounts of cobalt-60 were present in some of the samples collected since August outside building 310 in the 300 area. The maximum concentration in any one weekly sample (collected in December) was 0.01 pCi/m^3, 0.0001 percent of the AEC standard. Radiocobalt was not detected in any of the other air-filter samples, on or off the site. Work is performed in several buildings of the 300 area with a variety of radioactive materials, including fission and neutron activation products. The concentrations of fission products in the building 310 air-filter samples, however, remained the same as in samples collected elsewhere. The precise origin of the cobalt-60 has not yet been established.

Precipitation collected on the site contained the same fission products found in the air samples.

Composite monthly precipitation samples were also analyzed for iron-55. The average monthly concentrations ranged from 2.7 in February to 400 pCi/m^2 in April. The average for the year, 60 pCi/m^2 was a factor of three less than the 1969 average. Iron-55 is a neutron activation product and was produced mainly in nuclear tests conducted in September and October 1961. Therefore, the above concentrations have been corrected for decay to October 15, 1961, for comparison purposes.

Air sampling for argon-41, a beta-particle emitter with a 1.8 hour half-life that is produced in an operating reactor by the action of neutrons on the stable argon-40 in air, was conducted near the Juggernaut reactor (building 335) from January through April, and near the CP–5 reactor (building 330) from October to December. Between May and September neither reactor was in operation. The results are tabulated in table 3. Since the samples were collected downwind from the reactor after it had been in operation for several hours, the actual average concentration in the 300 Area was less than the values in the table.

The average and maximum concentrations of 82 and 2,230 nCi/m^3 are, respectively, about 2.1 and 56 times the AEC standard for uncontrolled areas and 0.04 and 1.1 times the AEC

Table 3. Argon-41 concentrations, 300 Area, October-December 1970

Month (1970)	Number of samples	Number of samples >20 nCi/m^3	Concentration[a] (nCi/m^3)		Percent of AEC standard	
			Average	Maximum	Average	Maximum
October	38	7	61	590	150	1,480
November	38	13	200	2,230	500	5,580
December	36	15	215	1,540	540	3,850
Annual summary	233	66	82	2,230	205	5,580

[a] Minimum detectable concentration—20 nCi/m^3.

standard for controlled areas. In this case, comparison with the AEC standards for controlled areas is appropriate since the sampling was conducted on the site.

The argon-41 concentration in the exhaust air from the Juggernaut was about 2.6×10^5 nCi/m³, so the average dilution by outside air, based on the average of 25 nCi/m³ for samples collected for the first 4 months of 1970, was about a factor of 10^4. The argon-41 concentrations measured in the vicinity of the CP–5 reactor (Building 330), which operates at a power level about 20 times higher than the Juggernaut, during the last 3 months of 1970 was 158 nCi/m³. In the CP–5 reactor the air that is exposed to neutrons is diluted with a large volume of inactive air before it is discharged. This means that the argon-41 concentrations in the air leaving the two reactor buildings are not greatly different, although the volume of air (containing argon-41) is about 15 times greater from CP–5. As a result, the argon-41 concentration in outside air averaged only six times greater near the CP–5 reactor, although the argon-41 production is about 20 times greater.

Air was sampled for tritiated (hydrogen-3) water vapor, near the CP–5 reactor. The results are given in table 4. The results were positive in all cases, although the concentrations were well below the AEC standards. This nuclide is produced continuously by several methods while the reactor is in operation.

In CP–5 the largest source is by neutron irradiation of the heavy water used for cooling and neutron moderating. The average concentration, 286 pCi/m³, was about 30 percent lower than in 1969. Samples were also collected twice a month in the east area, 2,000 yards from the reactor. In these samples the tritium concentration ranged from 1.2 to 37 pCi/m³ and averaged 12 pCi/m³. The east area samples generally varied in the same manner as the activity in the samples near CP–5 when the prevailing wind direction and velocity were considered. In general, east area samples were greater than 10 pCi/m³ on days when samples at CP–5 were greater than 100 pCi/m³ and the wind was from the southwest. The correlation is sufficiently good to conclude that most of the tritium in the east area came from CP–5. In addition, samples were collected twice a month from a control point located about 6 miles off the laboratory site. The tritium concentration in these samples ranged from 1.4 to 13 pCi/m³ and averaged 5.6 pCi/m³. No correlation between high results at CP–5 and offsite results could be determined. Although the reactor did not operate the first 9 months of 1970 due to rehabilitation, the heavy water, containing the long-lived tritium (12.3-year half-life) at a concentration of 1.5×10^9 pCi/ml, was handled and evidently small quantities escaped from the building.

Water monitoring

Argonne wastewater is discharged into Sawmill Creek, a small stream that runs through the Argonne grounds and flows into the Des Plaines River about 500 yards downstream from the wastewater discharge. Sawmill Creek was sampled upstream from the Argonne site and downstream from the wastewater outfall to determine if radioactivity was added to the

Table 4. Tritium concentrations in air, July-December, 1970

Month	300 area						East area				Offsite			
	Number of samples	Concentration (pCi/m³)			Percent of AEC standard		Number of samples	Concentration (pCi/m³)			Number of samples	Concentration (pCi/m³)		
		Avg	Min	Max	Avg	Max		Avg	Min	Max		Avg	Min	Max
July	43	452	18	2,680	0.22	1.34	1			31	1			6.3
August	32	556	10	2,510	.28	1.26	2	24	16	32	2	12	10	13
September	26	319	4.5	1,590	.16	0.79	2	16	14	18	2	3.8	3.0	4.6
October	26	160	2.2	1,240	.080	0.62	2	4.2	3.3	5.1	2	6.4	3.7	9.0
November	24	201	5.4	980	.10	0.49	2	21	4.6	37	2	3.6	2.5	4.8
December	24	94	1.2	433	.047	0.22	2	4.7	1.2	8.1	2	2.1	1.4	2.8
Annual summary	326	286	1.2	4,730	1.14	2.37	11	12	1.2	37	11	5.6	1.4	13

Table 5. Nonvolatile alpha and beta radioactivity in Sawmill Creek water Argonne National Laboratory, July-December 1970

Month	Location[a]	Number of samples	Alpha radioactivity (pCi/liter)			Beta radioactivity (pCi/liter)		
			Average	Minimum	Maximum	Average	Minimum	Maximum
July	Upstream	2	5.8	2.7	8.8	27	18	36
	Downstream	24	1.7	1.2	2.6	14	11	18
August	Upstream	2	4.0	3.2	4.7	29	24	34
	Downstream	20	1.8	1.2	2.1	18	14	22
September	Upstream	2	3.3	1.8	4.8	19	15	23
	Downstream	19	1.8	1.5	2.1	14	12	17
October	Upstream	2	3.5	1.1	5.8	22	12	31
	Downstream	21	1.3	.46	2.8	12	11	13
November	Upstream	2	1.0	.84	1.2	9.6	9.4	9.8
	Downstream	18	1.7	1.4	2.0	10	10	11
December	Upstream	2	1.3	.86	1.8	9.5	8.6	10
	Downstream	23	1.8	.76	2.4	9.4	7.5	11
July-December summary	Upstream	12	3.2	0.84	8.8	19	8.6	36
	Downstream	125	1.7	.46	2.8	13	7.5	22

[a] Relative sampling location with respect to Argonne wastewater outfall (figure 1).

stream in Argonne wastewater. The sampling locations are shown in figure 2.

Below the wastewater outfall the creek was sampled three to five times weekly. Since it was impractical to analyze all the samples for all the radionuclides and elements desired, equal portions of the individual samples collected each week were combined and analyzed. The results obtained in this way represent the average concentrations in the weekly samples. Above the site, samples were collected twice monthly and at least one sample each month was analyzed for each radionuclide of interest. The total alpha and beta radioactivities found in Sawmill Creek during July–December 1970 are given in table 5. Upstream from the Argonne site, the alpha activity was due primarily to radionuclides that occur naturally in the stream. Any additional activity downstream would indicate a detectable contribution from Argonne wastewater.

Although Argonne wastewater contained a small quantity of alpha activity, the results show that its addition to the creek did not increase the total alpha activity in the stream. Beginning in November, all water samples were filtered to remove suspended solids. This treatment reduced the alpha and beta activities appreciably, particularly in above-site Sawmill Creek and Des Plaines River samples, which contain suspended soil with its accompanying natural uranium and thorium.

The alpha-particle emitters most likely to be present in Argonne wastewater are isotopes of uranium, plutonium, and thorium. The alpha radioactivity in Sawmill Creek water due to these elements is summarized in table 6. The concentrations were low compared to the AEC standards.

The uranium content attributable to Argonne below the outfall ranged from 0.7 to less than 0.1 pCi/liter, depending on the relative

Table 6. Alpha-emitting elements in Sawmill Creek water Argonne National Laboratory, July-December 1970

Element	Location[a]	Number of samples	Concentration[b] (pCi/liter)			Percent of AEC standard	
			Average	Minimum	Maximum	Average	Maximum
Uranium	Upstream	6	1.4	0.84	2.0	0.004	0.005
	Downstream	57	1.4	.74	2.0	.004	.005
Plutonium	Upstream	5			<.05		<.001
	Downstream	55	.058	<.05	.36	.001	<.007
Thorium	Upstream	6	<.05	<.05	.08	<.003	.004
	Downstream	55	<.05	<.05	.06	<.003	.003

[a] Relative sampling location with respect to Argonne wastewater outfall (figure 1).
[b] For averaging purposes, individual sample results that were less than the minimum detectable concentration were assumed to be one half of the minimum detectable concentration.

amounts of natural creek and wastewater, about the same as during 1969. The amount of uranium in the wastewater, however, was too low to increase the total uranium concentration in the creek water. The thorium concentrations were normal at both locations. Small amounts of plutonium were found in a few below-outfall samples, and this plutonium evidently was added in Argonne wastewater.

In addition to the natural beta radioactivity in the creek, beta radioactivity from nuclear detonations was detected at both sampling locations and beta radioactivity from Argonne wastewater was found in some samples below the outfall. The normal nonvolatile beta radioactivity is approximately 5 pCi/liter above the site and 3 to 5 pCi/liter below the site, depending on the amount of dilution by wastewater. It is estimated that fallout activity added about 10 pCi/liter to the nonvolatile beta radioactivity at both locations (fallout is added to the water below the outfall directly from the air as well as by above-site water) and the Argonne contribution below the outfall averaged 1 pCi/liter. The Argonne contribution decreased to one-half of the 1969 levels, while the fallout contribution remained about the same.

The results of analysis of Sawmill Creek water for specific beta-emitting nuclides are summarized in table 7. The principal beta-particle emitter added to the creek by Argonne wastewater was tritium. About 80 percent of this nuclide below the outfall resulted from laboratory operations. Since this radionuclide is present as water (HTO), it is not included in the total nonvolatile beta activity in table 5. Separate samples were analyzed specifically for tritium. Although small amounts are produced by cosmic-ray interactions with the atmosphere, the bulk of the tritium in above-site water originated in nuclear detonations. The iodine-131 found below the outfall is believed to be due to fallout since this radionuclide was also widely present in air at the same time. Although some of the other nuclides listed were also added to the creek by fallout, the total concentration, regardless of source, must be used in assessing the health hazard of a radionuclide not naturally present in the environment. The percent of the AEC standard given in the table was calculated on this basis. As indicated in the table, the beta activities in the creek were very low compared to the AEC standards.

Since Sawmill Creek empties into the Des Plaines River, which in turn flows into the Illinois River, the radioactivity in the latter two streams is important in assessing the contribution of Argonne wastewater to the environmental radioactivity. The Des Plaines River was sampled once a month above the mouth of Sawmill Creek and twice a month below the mouth to determine if the radioactivity in the creek has any effect on the radioactivity in the river. The total radioactivity is summarized in table 8, and the results of analysis for specific elements and radionuclides are given in table 9. In

Table 7. Beta-emitting radionuclides in Sawmill Creek water Argonne National Laboratory, July-December 1970

Radionuclide	Location[a]	Number of samples	Beta radioactivity[b] (pCi/liter)			Percent of AEC standard	
			Average	Minimum	Maximum	Average	Maximum
Barium-Lanthanum-140	Upstream	6			<2		<0.007
	Downstream	57			<2		<.007
Cesium-137	Upstream	3			<.5		<.003
	Downstream	57			<.5		<.003
Tritium	Upstream	6	450	<200	660	.015	.022
	Downstream	125	1,400	460	6,000	.047	.20
Iodine-131	Upstream	1			<3		<1
	Downstream	125	<3	<3	6.1	<1	2.0
Strontium-89	Upstream	6			<2		<.07
	Downstream	57			<2		<.07
Strontium-90	Upstream	6	1.2	.54	1.5	.40	.50
	Downstream	57	1.4	.93	2.1	.47	.70
Technetium-99	Upstream	3			<.5		<.0002
	Downstream	57			<.5		<.0002

[a] Relative sampling location with respect to Argonne wastewater outfall (figure 1).
[b] For averaging purposes, individual sample results that were less than the minimum detectable concentration were assumed to be one half of the minimum detectable concentration.

Table 8. Average radioactivity in Des Plaines and Illinois River water, Argonne National Laboratory July-December 1970

Location	Concentration (pCi/liter)			
	Nonvolatile alpha radioactivity	Uranium	Nonvolatile beta radioactivity	Tritium
Des Plaines River[a] (above Sawmill Creek)	[b]2.3 (6)	1.5 (2)	14 (6)	440 (3)
Des Plaines River[c] (below Sawmill Creek)	3.2 (12)	1.5 (6)	16 (12)	460 (12)
Illinois River[d]	.89 (3)	.67 (1)	7.7 (3)	330 (1)

[a] Sampled near Route 45, upstream from the mouth of Sawmill Creek.
[b] Number in parenthesis is number of samples.
[c] Sampled near Lemont, downstream from the mouth of Sawmill Creek.
[d] Sampled at McKinley Woods State Park, Morris and Starved Rock State Park.

contrast to previous years, the concentration of tritium in the Des Plaines River below the mouth of Sawmill Creek was not measureably higher than above Sawmill Creek.

The concentrations of the other radionuclides and the total alpha and beta radioactivities were in their normal ranges at both locations. The annual average beta radioactivity (15 pCi/liter) was about the same as in 1969. The natural nonvolatile beta radioactivity in the river is 5 to 10 pCi/liter, and the excess (about 7 pCi/liter) was due to fallout. The total radioactivity in samples of Illinois River water was similar to those found in other bodies of water in the area and to activities found previously at these same locations. No radioactivity originating from Argonne could be detected.

Radioactivity in milk

Raw milk was collected monthly from a local dairy farm and analyzed for several fission products. Iodine-131 was not present in concentrations greater than the minimum detectable amount of 20 pCi/liter. Barium-140 was detected in the November milk sample at a concentration of 1.7 pCi/liter, while the strontium-89 concentration was 4.7 pCi/liter in this sample and 1.9 pCi/liter in the December sample. The cesium-137 and strontium-90 concentrations are given in table 10. All the fission products originated in nuclear tests and their presence in milk is not related to Argonne operations. The average strontium-90 content changed little from last year, while the cesium-137 concentrations were about 35 percent lower.

Conclusion

Argonne's contribution to the environmental radioactivity was primarily limited to tritium and argon-41 in the air and to tritium in water

Table 9. Radioactivity in Des Plaines River water Argonne National Laboratory, July-December 1970

Radionuclide	Location[a]	Number of samples	Concentration[b] (pCi/liter)		
			Average	Minimum	Maximum
Barium-lanthanium-140	Upstream	0			
	Downstream	0			
Cesium-137	Upstream	0			
	Downstream	3			<0.5
Tritium	Upstream	3	440	360	500
	Downstream	12	460	<200	690
Plutonium (alpha)	Upstream	2			<.05
	Downstream	6			<.05
Strontium-89	Upstream	1			<2
	Downstream	2			<2
Strontium-90	Upstream	1			1.4
	Downstream	2	1.5	1.5	1.6
Technetium-99	Upstream	0			
	Downstream	3			<.05
Thorium	Upstream	2	.06	<.05	.10
	Downstream	6	.05	.05	.12
Uranium (alpha)	Upstream	2	1.5	1.3	1.7
	Downstream	6	1.5	.85	2.0

[a] Relative sampling location with respect to Argonne wastewater outfall (figure 1).
[b] For averaging purposes, individual sample results that were less than the minimum detectable concentration were assumed to be one half of the minimum detectable concentration.

Table 10. Fission product concentration in milk July-December 1970

Date collected	Concentrations (pCi/liter)	
	Cesium-137	Strontium-90
July 1	20	11.3
August 5	10	7.7
September 2	<10	6.7
October 7	20	7.0
November 10	15	6.6
December 2	<10	8.3
Average	14	7.9

from Sawmill Creek. The only activity detected off the site was tritium in Sawmill Creek. Fallout from nuclear detonations continued to be the principal source of non-natural radioactivity in the environment and occurred at about the same level as during 1969.

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January 1972

Correction:

The following footnote was inadvertently left out of the report entitled "A Joint X-ray Radiation Survey in Puerto Rico, 1968" by Michael Gileadi:

[2] The responsibility for radiation protection and control (associated with the use of radiation in medicine, education and commerce in Puerto Rico) rests with the Radiological Health Program in the Department of Health of the Commonwealth of Puerto Rico.

The article appeared on page 495 of the October 1971 issue of Radiological Health Data and Reports, and the footnote refers to the end of the first paragraph of the article.

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